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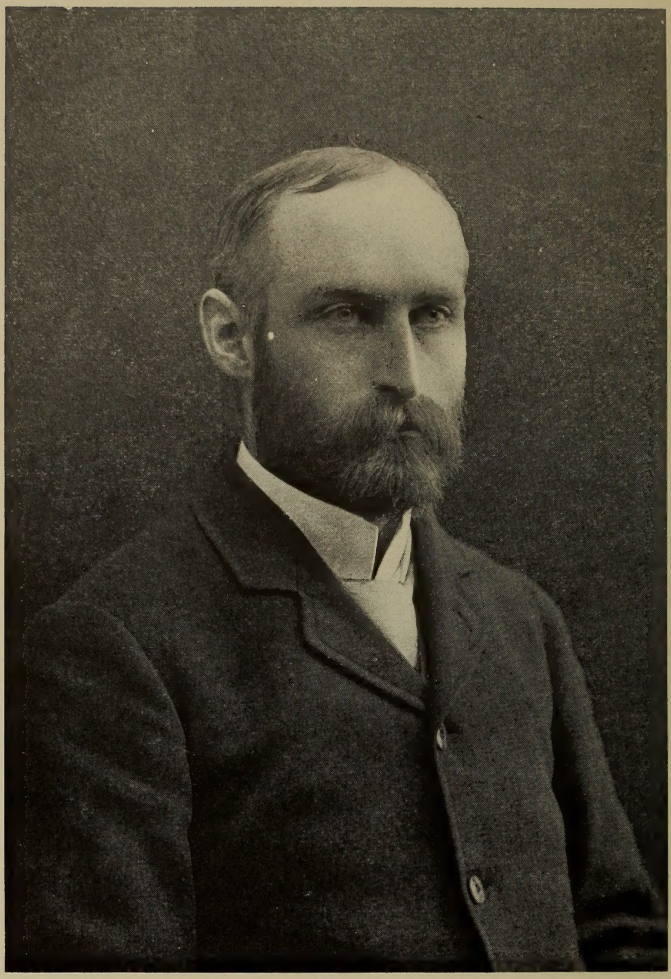

No. 16 1902-1903

TRANSACTIONS

OF THE

ENGINEERING SOCIETY

OF THE

School of Practical Science

TORONTO

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PREFACE.

This volume contains most of the papers read before the Engineering Society of the Ontario School of Practical Science during the session 1902-1903; also four papers which were received too late to be presented before the members, by Prof. Stewart of the School, by Messrs. Shipley, Mitchell, and McDowall, three of our many successful graduates.

The papers nearly all deal with practical problems in engineering, and were presented to the members with many lantern-slide illustrations. Sufficient of these illustrations have been included to make clear the detailed information in the text.

The thanks of the Society are tendered to all who have by their contributions so greatly added to its usefulness, especially to the loyal graduates who are ever ready to spend time and energy for the good of the Society.

With much pleasure we offer to our readers a portrait of the Principal of our School, Professor Galbraith.

This edition consists of 1,500 copies. A list of exchanges is printed elsewhere.

Toronto, April 9th, 1903.

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LATE LECTURER IN APPLIED MECHANICS, SCH. PR. SCIENCE.

BY PRINCIPAL GALBRAITH.

John Andrew Duff was born thirty-seven years ago near the village of Cookstown in the County of Simcoe, where his people had settled early in the last century. He received his early training at the Collingwood High School, and entered the University of Toronto in 1883, taking first class honours in Mathematics. Shortly after this time he received a commission as lieutenant in the 35th regiment of Canadian militia. When the North-West rebellion broke out in 1885 he served through the campaign with K Company (the University company) Queen's Own Rifles, and was granted his year, in common with other members of the company, without examination by the Senate of the University. He obtained honours in 1886, and graduated B.A. with honours in Physics in 1887. In 1886 three companies of the 35th regiment were transferred to the 36th and Lieutenant Duff with them. In 1887, having decided upon civil engineering as his profession, he entered the School of Practical Science and graduated in 1890. In 1888 he became captain of No. 3 company, 36th regiment, and in 1892 was promoted to the rank of major. In 1890 he entered the employment of the Rotary Steam Snow Shovel Co., Paterson, N.J., and the following year was with the New Jersey Steel and Iron Co. He was the first principal of the Toronto Technical School, and held this position from December, 1891, to September, 1894, when he resigned on being appointed lecturer in Applied Mechanics in the School of Practical Science. From 1891 to 1894 he also served as fellow in Applied Mechanics in the School of Science. In 1890 he joined the Canadian Society of Civil Engineers as a student, and was transferred to the rank of associate member in 1896. He was also a member of the Canadian Institute and of the Engineering Society of the School of Science, and contributed valuable papers to the transactions of these societies. A portion of his work in which he took special interest was the construction of roads and pavements. In this connection he had begun an investigation of the resistance and endurance of various road and

street coverings. The last testing machine which he set up in his laboratory was an abrasion measuring apparatus for use in this work. Shortly after his appointment he became interested in Forestry and the investigation of Canadian timbers, and began systematizing the timber tests carried on in the school along the lines originated by Bauschinger and developed in the United States by the late Professor I. B. Johnson in connection with the "United States Timber Tests," inaugurated in 1891 by Dr. B. E. Fernow. Just before closing his active connection with the school Mr. Duff was engaged in preparing a laboratory for making time tests of the strength and elasticity of timber, a most important branch of the subject. The limited number of experiments which have been made seem to indicate that the strength of timber under long continued loads is but little more than half that indicated by the ordinary tests. It is to be hoped that these investigations, so unfortunately broken off, may be soon resumed. In the session 1898-99 he organized a system for examining the conditions of growth of the pine timber of the Algonquin Park, and selecting and marking trees for testing in the laboratories of the school. He spent a part of the summer of 1900 and the winter and spring of 1901 in Algonquin Park carrying out this work, as well as his diminishing strength would permit, but was obliged to relinquish it and try a change of scene. He spent the summer of 1901 in western Alberta and the mountains. In October, 1901, he made a brave endeavour to resume his work at the School, but the strain was too great for his weakened frame. He went to his home at Cookstown, where he lived with his brother, Mr. J. S. Duff, M.P.P., until his death, which occurred on the night of March 12-13, the immediate cause being a hemorrhage. He was buried with military honours in Wilson Cemetery on Sunday, March 15th.

He took a great interest in the movement for reorganizing a University company, of which the final outcome was the Toronto Engineer Company. At his death he was senior major of the 36th (Peel) regiment, and had it not been otherwise ordained, would in ordinary course have become lieutenant-colonel in command in January, 1904, on the retirement of Lieutenant-Colonel G. T. Evans through effluxion of time.

In 1889-90, his last year as a student, he was president of the Engineering Society of the school. No better picture of the thoughtful and sympathetic nature of the man can be presented than the one unconsciously traced by himself in his presidential address to the society. Naturally reserved and self-contained, he was yet a favourite wherever his lot was cast. As student or teacher, in the camp or on the farm, everyone had a good word for John Duff. Unselfish and kindly, he never spared himself to serve a friend. He loved little children, birds and animals, and studied their ways with curious interest. A keen sense of humour saved him from taking men and things too seriously. Of the mental fibre of a Stoic philosopher, his outlook on life was wonderfully sane and temperate.

In one respect, however, philosophy was of no avail: devotion to duty became with him an uncontrollable passion. Always busy, he was never content however well done his self-allotted task might be. Regrets now are useless; it is difficult nevertheless not to feel that he might still have been with us had he been more sparing of his strength. His ideal may best be expressed in the words he seemed to have made his own:

"And only the Master shall praise us, and only the Master
shall blame;
And no one shall work for money, and no one shall work for
fame,
But each for the joy of the working, and each, in his separate
star,
Shall draw the Thing as he sees It, for the God of Things as
they are."

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ENGINEERING SOCIETY

OF

The School of Practical Science

TORONTO.

PRESIDENT'S ADDRESS.

GENTLEMEN:—

It is with great pleasure that I take this opportunity of thanking you for the honor conferred in electing me to the highest position at your disposal, namely, President of the Engineering Society. I thank you also for the energetic committee you have elected to assist your President in the transaction of the business of the Society, and it is unnecessary to say that they will discharge their duties in a business-like manner.

Having in mind the ability of former Presidents and the high standard placed before me, I feel, gentlemen, that I can but inadequately discharge the various responsibilities which necessarily devolve upon me in my present capacity; but I assure you that my feeble efforts have been and shall be directed towards making our Society both interesting and beneficial to all our members. Our Society has had such a phenomenal growth that now we have a membership in the neighborhood of 350, not including life members. If success depended on me alone, failure would be sure to follow, but with the co-operation of the members of such a Society, success is inevitable. I ask you therefore, gentlemen, to give your committee every possible assistance in making our meetings a success.

We are glad to have the opportunity of extending the hand of welcome to the gentlemen of the first year who have recently become members, and we want them to recognize the fact that the Society is as much for them as for the members of the senior years.

A number of things in connection with the Society might be referred to, but they have been so often enlarged upon by former Presidents that I feel like passing them over. However, a few are of such importance, that I find it necessary to refer to them, especially for the benefit of the members of the first year.

The purpose of the Society, as its name suggests, is the investigation and discussion of all subjects of an engineering nature, and the cultivation of a spirit of mutual assistance among its members. Be ready to discuss the subject before the meeting at any time; and if you can prepare a paper on any engineering subject, do so and read it for us. Should you know any one who could assist us, I will be pleased to make the necessary arrangements.

At the present time an event of great importance to the students of the School of Practical Science, and in fact to the people of America, is taking place. I refer to the new building in connection with the Faculty of Applied Science of Toronto University. From present indications the members of the fourth year will not reap much benefit from it, but every graduate rejoices at the prosperity of his Alma Mater. This is certainly a good sign of the times, namely, more advanced technical education. Professor Dewar, an authority on practical chemistry, in an address before the British Association, which met recently at Belfast, remarked that "England had lost many great industries owing to the lack of education among the so-called educated classes." He payed a great tribute to the German Universities, and confesses that "the German population has reached a point of general training and specialized equipment which England could not attain without two generations of hard and intelligent work." We are glad to note that Canada is taking the proper steps to be in line with other progressive countries in the matter of technical education.

The Engineering Department of Toronto University occupies a very important position in that institution and this is due to a very great extent to the executive ability and persevering efforts of Principal Galbraith. All graduates and undergraduates were pleased to see that the Senate of the University recognized his efforts by conferring upon him the degree of LL.D. honoris causa.

"The Rise and Progress of Engineering."

I assure you, gentlemen, that I had some difficulty in deciding upon a subject on which to write an address, as former Presidents have

written on the subjects suitable for such. After due consideration I resolved to give a short account of the "Rise and Progress of Engineering," dealing chiefly with the former. Being limited in space I must of necessity be very concise in my remarks.

As members of the engineering profession we should be more or less familiar with its early history, and also that of the men who elevated it to the place of a distinct profession. As the history of a nation is that of its prominent men, so the history of engineering is that of its prominent engineers. It is within recent times that engineering became a distinct profession, yet it must be admitted that it is one of the oldest, if not the first, to which men turned their attention. Our universe is governed on sound engineering principles, and its Creator established laws which are infallible. Creation itself was the first work of an engineering nature. The function of the engineer is to utilize the forces of nature for the benefit of mankind. Thus since creation we have always had engineers whether designated as such or not.

The mind is always attracted by that period in the world's history with which are coupled the great names of antiquity, and by reading such the engineer learns many interesting and instructive lessons. It is instructive to note the condition of affairs at this period among our forefathers from an industrial point of view, and to trace the cause of the many mechanical improvements made from time to time.

During the dark ages in any nation's life, few, and indeed very rude, are the instruments used by its people, but as they emerge from the cloud of barbarism, and civilization dawns, improvements appear and the operations of daily life are performed with less manual labor.

The Oriental nations, such as the Chinese and Hindoos, attained a comparatively high state of civilization more than a thousand years before the Christian era. The plough, the spindle and the loom have been known from the earliest times, and many branches of Science, as Astronomy, Geometry and Mathematics, were cultivated. What is the reason then that more rapid advancement has not been made? In fact, for many centuries, instead of the countries becoming more civilized and thus more progressive, they seem to have drifted back towards barbarism. The reason is not found in the natural deficiencies of the people, nor from the want of the higher powers of intellect which constitute genius in every age; but in the principles of government united with the religious teachings of the times. Wherever the

above conditions hold, the inventive faculties are always deadened and the energies paralyzed.

Egypt is an example of a country where a high degree of civilization was attained at an early period, and where the arts flourished; while at the present time there remain but the ruins of its temples, pyramids, and many public buildings, which show that the people cultivated practical science, and that there were engineers who applied it in the construction of those memorials of antiquity. According to different authorities the pyramids of Egypt date back from 2,700 to 3,700 years B. C., and they are generally considered to be among the earliest constructions where the services of the engineer were engaged.

The early inhabitants of Egypt made considerable progress along industrial lines. The remains of their rich and distinguished men are found to be shrouded in linen, thus indicating that they had discovered the art of weaving and spinning. Also in their agricultural pursuits they resorted to irrigation.

After the Egyptians we come to the Greeks, who surpassed all others, ancient or modern, in the refinements of architecture and sculpture. To this people we owe the true principles of harmony and beauty of design. They were original in their conceptions and made the study of nature the high road to perfection. Symmetry in the development of natural forms was the criterion by which the artist was judged. With all our boasted powers of invention, no order of architecture has ever been originated to be at all compared with any of the fine orders handed down to modern nations by the noble Greeks.

It is very unfortunate for the cause of Scientific Engineering that the constant wars carried on by the Greeks against the Macedonians and other powers seem to have sapped their liberty from them, and to destroy every hope of further development in the art of architecture, leaving them in a position to be easily conquered by the Romans, who practically became masters of Europe.

For many works of art and of a mechanical nature we are indebted to the Romans. Water, as a motive power, was first utilized by them in grinding corn and pumping water. However, generally speaking, all works of an engineering nature, carried on under Roman rule, were executed by foreigners, either Greeks or Tuscans. The chief object of the Romans was the gratification of their desire for pleasure. They had magnificent edifices and monuments constructed, which are

still to be seen in Italy. In England, also, the roads and causeways built by the Romans in Cæsar's time are yet to be seen. Notwithstanding the fact that many works of an engineering nature were constructed by the Romans, the luxury and indolence of the people resulted in a period of stagnation in Science, and ultimately in the fall of the Roman Empire.

For almost a thousand years after the downfall of Rome little attention was paid to the science of engineering in Europe. As engineering goes hand in hand with civilization, we are not surprised that this period is called the dark ages. About the middle of the fifteenth century, however, the light of civilization began to dawn again, and it was about the time of the birth of Michael Angelo, one of the world's most famous painters, sculptors and architects, that the tide changed.

Galileo, as the representative of theoretical and experimental science, followed Michael Angelo, and to him we owe the telescope and pendulum, afterwards applied by his son to the regulation of time-keepers. His discoveries revolutionized the science of Astronomy.

At this period we may say that modern engineering begins. The Marquis of Worcester in his "Century of Inventions," announced the steam-engine, although steam as a motive power was used many centuries previous to this in the form of the steam turbine, a branch of mechnical engineering that is receiving a great deal of attention at the present time. The Marquis had an engine of about two-horse power built, which was used for pumping water from the Thames. However crude the invention, it must be regarded as the starting point from which the modern steam-engine was developed.

Captain Savery introduced steam generally as a means of raising water. This was accomplished by means of two receivers and two boilers.

In 1705 Newcomen introduced a new engine which was more economical than Savery's, and known as the atmospheric engine. In 1775 Smeaton constructed an engine on the same principle as that of Newcomen. The great waste of fuel and steam brought Watt's inventive genius into play, and ultimately led to the discovery of the double-acting steam-engine of modern times. In the earlier engines the valves were worked by hand, but by the ingenious contrivance of a lad, Humphrey Potter, strings were attached to the valves, which were then opened and closed by the mechanism of the engine. After-

wards the strings were replaced by gears, which made the engine self-acting.

Up to the year 1750 in the history of Engineering the title of Civil Engineer was unknown in the vocabulary of Science. We must not conclude, however, that there were no engineers, but engineering as a distinct profession was not established till the time of Brindley and Smeaton. Previous to this, all works of an engineering nature were carried on by architects and millwrights.

John Smeaton, who lived from 1724 to 1792, may be called the father of modern engineering. In early life he was a barrister, but his natural propensities were along other lines. He acquainted himself with practical mechanics, and had the genius to apply them successfully in the construction of public works. Before his time Great Britain was devoid of bridges, canals and hydraulic works. He also introduced blowing machinery into iron works. The work which demanded the greatest engineering ability, and which stands to-day as a proud monument to his fame, unmoved by the storms of more than a hundred years, was the Eddystone Lighthouse. It was Smeaton's greatest work, and is considered among the most arduous undertakings that have fallen to any engineer.

After completing the Eddystone Lighthouse in 1759, he read a paper before the Royal Society on "An Experimental Enquiry concerning the Native Powers of Water and Wind to turn Mills and other Machines depending on Circular Motion." From this time he was recognized as an engineer of undoubted ability, and he was consulted on almost all projects within the province of engineering. "He was an incessant experimenter," and James Wall, his contemporary, once remarked that, "His example and precepts have made us all engineers." His success was due to the fact that he never trusted to chance, nor yet did he base his constructions on theory alone, but where possible he founded his constructions on experiments.

In the same field of study was Brindley, one of nature's own engineers, who commenced life as a millwright with practically no education, but who by his indomitable perseverance, has left behind him lasting monuments of his resources. He is called "the father of inland canal navigation in England." He was also engaged in the construction of millwork and water engines used in raising coal from mines. He also constructed a steam-engine at New-Castle-under-Tyne, but we are not informed as to how it worked. The scheme was

opposed and defeated by some interested competitors. The crowning efforts of his life, however, were the building of the Great Bridgewater Canal and the Viaduct across the Irwell, at a height of forty feet above the river. In addition to these we are indebted to this genius for the penetration of mountains by tunnels.

While Smeaton and Brindley were engaged in the construction of public works, other minds were at work along other lines, and to them we owe the new era in mechanical progress. The name of James Watt is quite familiar to every engineer as it is stamped as indelibly upon the steam-engine as Newton's is upon the law of gravitation. The earlier steam-engines may be regarded as steam-pumps, with that of Newcomen as the connecting link between the steam-pump and the modern engine. Brindley, Smeaton, and other engineers, improved Newcomen's engine, which remained in use till the beginning of last century; but in effect it remained the same until the time of Watt, "the result of whose labors has been a harvest of wealth, prosperity, and ingenuity, without a parallel in the history of the world." James Watt was born at Greenock, Scotland, in 1736, and being of rather delicate health was allowed to choose his own occupations and amusements. His father was a mechanical instrument maker, the use of whose tools young Watt soon mastered. He was afterwards sent to a commercial school where he studied classics and mathematics, being very successful in the latter. At the age of twenty he became mathematical instrument maker to Glasgow University, and there he drew around him many friends, one of whom remarked, "I saw a workman, and expected no more; but was surprised to find a philosopher as young as myself, and always ready to instruct me."

About the year 1762, with one of Newcomen's engines, belonging to Glasgow University, as a model, Watt turned his inventive faculties to the steam-engine, and the result was first the single-acting and afterwards the double-acting steam-engine. True, it was in existence before his time, but it was neither economical nor practical; and it remained for him to improve it so as to give it both these characteristics. It is in principle to-day what it was when it left the hands of Watt. It has still the same mechanical organization although moulded into a great variety of forms.

In 1800 he retired from active work, but busied himself with several inventions and the application of steam to the presses. He re-

tained his intellectual vigor till the time of his death, which occurred at Heathfield in 1819.

Closely identified with the history of the steam-engine is that of George Stevenson, at one time a locomotive stoker, but subsequently the originator of the railway system. Locomotives came into use in 1804, and during the next 20 years the speed was raised from 4 to 7 miles an hour. The learned men of the time considered a higher speed impossible, but where learning failed, natural genius triumphed when Stevenson invented the tubular boiler and thus raised the speed from 7 to 30 miles an hour. His inventions came at the right time and set the question of the railway and the locomotive engine at rest forever. The two great principles which made the locomotive a success were the sufficiency for traction of the smooth rail and wheel, and the application of the steam-blast up the chimney. The problem of making the smooth wheel adhere to the smooth rail, or in the language of Stevenson, of making them "man and wife," is due to the genius of William Headley.

The establishment of the locomotive necessitated the construction of railways, which has ever since formed a very important branch of engineering. The first constructed was the Liverpool and Manchester line, commenced in 1826 and completed in 1829. George Stevenson organized all the work himself, having to contend with the many difficulties which present themselves in railway construction, and it is well to remember that he had no example to guide him. He had hills to surmount, quagmires to make firm, tunnels to construct and upwards of 100 bridges to build, with the numerous details with which the engineer is quite familiar.

The invention of the railway has bestowed more benefits upon mankind than anything else resulting from human ingenuity. It has brought profit, comfort and luxury to all classes, while its benefits to the commercial world cannot be contemplated.

We have briefly narrated the triumphs of steam in its application to land transportation, and, if space permitted, we might narrate also its triumphs as applied to navigation, mining, the various industries and to the generation of electricity.

I have attempted a very brief account of the lives of four of the most prominent engineers up to the beginning of last century. Many others might be given, but into the lives of these is interwoven the

history of engineering, so that, giving one, necessitates the giving of the other. The engineer starting in life may learn many lessons from the biographies of those men, who elevated engineering to the plane of a distinct and an honored profession.

It is not my purpose to deal with the progress made during the last century, as such would be impossible in this address. During this period more advancement has been made in engineering than for thousands of years previous. The marvels of the past century in the Science of Engineering are innumerable. Electricity in its various applications is, no doubt, the wonder of the age. Discovery followed discovery, and invention, invention, till the mere dreams of scientific men of the past are the realities of the present. Looking back at the marvellous achievements in electricity, what can't we hope for in the future?

It will be noted that the word "Engineer" has been used in its broadest sense. In fact it is within recent years that engineers have been classified into Civil, Mechanical, Electrical and Mining, and this is due to the great specialization of the present day.

In conclusion, gentlemen, whatever department you devote your attention to, have a high ideal, remembering, that before your expectations are realized, you must begin at the bottom, and reach the highest plane of your profession by the portal of persevering industry.

D. SINCLAIR.

SOME PRACTICAL NOTES ON STREET PAVEMENTS.

CHAS W. DILL, '91, A. M. CAN. SOC. C. E.

So much has been written on pavements and paving work during the past few years that it is difficult to give any new or original matter apart from what has been thoroughly discussed in Engineering Magazines and Periodicals. Owing to this I have decided to refrain from going into technical details, as I believe a few observations derived from practical experience will be equally helpful to the student body of our school.

ASPHALT.

As the most expensive, and perhaps the best of modern pavements, I will first deal with asphalt. In our construction we find that a thoroughly consolidated sub-grade is one of the vital requisites of a permanent pavement and particular attention should be paid to this matter. Asphalt pavements are divided into two classes—heavy and light—so called because of the condition of the traffic on the street to be paved. The heavy asphalt consists of a 6-inch concrete foundation, a granolithic gutter 14″ wide next the stone curbing, a binder course 1″ in thickness, and a 2″ asphalt surface coat. The concrete is composed of 1 part of accepted Portland cement, 3 parts of suitable sand, and 7 parts of clear broken stone. The following are some of the requirements of Toronto specifications for quality of materials. The cement is required to pass the following tests made in the City Engineer's office:

"(*a*) A neat tensile strain of not less than 150 lbs. per square inch after 24 hours in water after "hard" set, and 400 lbs. per square inch after 24 hours in air, and six days in water; and a tensile strain of 125 lbs. per square inch after 24 hours in air and six days in water, and 190 lbs. per square inch after one day in air and 27 days in water when mixed, one part of cement to three parts of standard sand, and rammed into moulds.

(*b*) Cement on being sifted through a sieve of 10,000 meshes per square inch (wire No. 100 guage), must not leave a residue of more than 10% by weight.

(*c*) Cement shall have a specific gravity of not less than 3.09 nor more than 3.25, as determined by a voluminometer, and must be free from lumps and be finely ground.

(*d*) Neat pats of cement shall stand without checking, warping or discoloration any recognized tests for soundness.

(*e*) Cement submitted to chemical analysis shall not contain more than $1\frac{3}{4}\%$ of sulphuric anhydride, nor more than 3% of magnesia (oxide).

(*f*) Color pats of neat cement immersed in water or left in air shall show a uniform color free from patches or discoloration or blotches or pit holes of any kind at the end of one day or one week.

(*g*) Briquettes of neat cement shall require at least 20 minutes to develop "initial set."

The city may require a certificate from the manufacturer to the effect that the cement furnished has been seasoned, or subjected to aeration for at least thirty days before leaving the works. The contractor should always have on hand, and keep in store at least six days before required for use, a sufficient quantity of cement for the work he has to do, so as to keep the men engaged upon it, continuously employed for at least six days ahead.

This cement should be kept under proper protection on or near the works, one of the objects of this requirement being that tests may be made of each batch of cement at least five days before it is used.

All sand required for concrete should be free from dirt, dust, loam or any other impurity or foreign matter; it should be clean, coarse and sharp.

All broken stone should be solid, compact, suitable in all respects and subject to the Engineer's approval; no stone or particle should exceed 2 inches nor be less than $\frac{3}{4}$ inches in length or breadth. All stone should pass through a 2-inch ring, and should be screened and free from dirt, and such dust as may, in the Engineer's opinion, be considered objectionable.

These requirements apply to all classes of paving work in which concrete is used.

The concrete is mixed in batches of half a cubic yard on a tight smooth platform (preferably a sheet iron plate), the sand and cement being thoroughly mixed dry, when sufficient water is sprinkled over the mixture to make a moderately thin mortar, to which is then added the previously moistened crushed stone, and the whole mass shovelled up into a heap in the centre of the platform. The whole mass is then thoroughly turned over again and mixed, as often as directed by the Engineer or Inspector before being removed from the platform. When spread on the street the concrete is thoroughly rammed with square wooden rammers, and the finished surface made to conform truly to the lines and levels shown on the drawings.

The concrete is sprinkled occasionally to retard setting and prevent cracking, and is left from 5 to 7 days before the wearing surface is applied.

On residential streets with light traffic a two-inch asphalt surface is applied on the concrete foundation(which is 4 in. in thickness), while on business streets or on streets with street car tracks a binder coat of one inch thickness is used before applying the asphalt surface, the concrete foundation in these cases being 6 in. in thickness.

Owing to the long term of guarantee demanded (10 years) we do not go into particulars relating to the proportions of the paving mixtures nor of the sand and stone dust used in the mixtures, but simply make tests as the work progresses, as we feel that the contractors are vitally interested in securing the best possible results, and they are always willing to correct any appreciable variations in the mixtures, etc., when not in accordance with the Engineer's opinion.

When tenders are received we require contractors to state the brand of asphalt he proposes using, and if necessary, to furnish proper certificates of shipment, or other satisfactory evidence, showing the exact locality from which the asphalt, or any of the ingredients used, have been obtained. Samples of the asphalt and other ingredients are required to be furnished before being used on the paving work, so as to permit proper tests being made.

The following are the requirements as to quality of work: "The asphalt and all mixtures therewith, must be suitable and of the very best quality, subject in all respects (including proportions) and at

any and all times, to the Engineer's inspection and tests, and also to his approval or rejection; and shall afford the City Engineer or his agents free access to the works where the asphalt is treated or mixed, for the purpose of analyzing or inspecting the same. The same restrictions and conditions shall also apply to the binder or cushion coats used, to the manner and method of mixing and of laying the same, or of any of them, all of which must be performed and done in the very best and most approved manner, and with suitable and approved plant, by qualified and skilled persons, who have had sufficient experience in such operations in the Engineer's judgment, to justify their employment in or about the works, or in any way in connection therewith."

Asphalt should be laid only in dry and suitable weather on a perfectly dry foundation which should always be swept off perfectly clean immediately before applying either the binder course or the wearing surface. Experience has shown that the paving mixture at a temperature of even 300° Fahr. does not evaporate the moisture properly before chilling the surface in contact with the damp concrete and in that way prevents a bond between the foundation and wearing surface. Naturally this is a hardship at times, as the contractor's plant may be several miles from the street being paved, and a sudden summer shower may cause the loss of several loads of paving mixture already on the way from the plant to the streetwork.

For years on all streets paved with asphalt the asphalt wearing surface was carried to the stone curb forming the gutter also, but in most cases the water rotted the asphalt along the curb, causing the mixture to rapidly distintegrate. To prevent this a concrete (granolithic) gutter from 14 in. to 16 in. in width was substituted which has removed this trouble. This concrete is laid on the concrete foundation, and is composed of 2 parts of cement to 3 parts of approved crushed granite, no particle of which shall be over $\frac{5}{8}$ in. in length or breadth. The surface of the concrete gutter is kept $\frac{1}{4}$ in. lower than the asphalt so as to ensure that no water remains in contact with the asphalt. On streets with light travel a further change was made some three years ago in adopting a combined concrete curb and gutter. This makes a very neat appearance, and as it is laid on the concrete foundation of the street it makes a complete bond across the street from curb to curb. It has an additional advantage in reducing the cost of construction quite materially.

Bituminous Macadam.

Bituminous macadam because of its similarity to asphalt naturally comes next, and in this I will also include tar macadam. The tar macadam being older and leading up to the bituminous macadam should be taken up first. It consists of an ordinary broken stone macadam foundation with one or more layers of stone coated with tar or a mixture of tar and paving pitch.

Our standard tar macadam pavement is laid on residence streets with only ordinary traffic, and consists of 8 inches of broken stone, the upper 4 inches of which, consisting of two layers, are treated with a mixture of tar and paving pitch. The sub-grade foundation is prepared and rolled as for any other pavement and a 4-in. layer of coarse broken stone, no particle of which should exceed 4 inches in length or breadth, and not more than 5 per cent. should be less than $1\frac{3}{4}$ inches. After being evenly spread so as to present a uniform surface it should be rolled with the steam roller to thoroughly bed the stone, after which a layer of coarse, clean sand is spread upon it, sufficient to fill all voids and the surface then well wet and rolled, more stone and sand being applied where and as required, and the rolling and watering continued until an even, hard, and uniform surface, conforming to the required lines, levels, and cross-section, is obtained. The first course of tarred stone 3 in. in depth, composed of good, hard, tough limestone, $1\frac{1}{2}$ in. in greatest length or breadth, not more than 5% of which should be less than $\frac{3}{4}$-in., mixed with paving pitch and tar, is then spread evenly and raked if necessary to give a uniform surface, and thoroughly rolled, after which the top course of tarred stone one inch in depth, composed of good hard, tough limestone, as nearly uniform in size as possible, no particle being more than $\frac{1}{2}$-in. nor less than $\frac{1}{4}$-in. in length or breadth, mixed with paving pitch and tar, is then spread and evenly raked, after which it is thoroughly rolled. A thin uniform coating of stone screenings is then spread over the surface and thoroughly rolled so as to fill all interstices, the rolling being continued until the surface is perfectly hard, compact and even, and the surface of the top course of stone (not including the covering of limestone dust) must not in any place be below the lines and levels shown on the cross-section plan, nor be more than 1 inch above the same.

The tar must be coal gas tar, as other tars have not the proper qualities for this work, and the paving pitch is a tar product from

which have been distilled certain other products at a high temperature. The stone to be tarred should be heated on an iron floor under which are flues from a fire until the moisture is driven out. The coal gas tar should be added to the previously melted paving pitch in equal quantities by weight, and the mixture heated in large iron kettles (of at least 50 gallons capacity). The heated mixture should then be added to the stone, handling with buckets from a faucet being the simplest and easiest method, and the whole mass heaped together and mixed until each particle of stone is thoroughly coated and the mixture drawn and spread on the street while hot. Experience has shewn that a cubic yard of stone requires about eleven imperial gallons of the tar and paving pitch mixture to ensure thorough coating. The presence of water in the tar will cause the mixture to froth and foam and consequently deceive one in regard to the quantity required. The difficulty in securing proper tar and paving pitch for this pavement, the inferior kinds showing a lack of "life" and "elasticity" so essential to the permanency of a pavement, led certain parties to experiment with different mixtures with a view to prolonging the "life" of the tar macadam, and these experiments resulted in a patent tar macadam pavement being introduced in the States under the name of "Warren's Bituminous Macadam Pavement." The more essential points of difference being, (1) the broken stone foundation is coated with a patent composition to ensure a bond with the succeeding layer of coated stone, instead of the sand filling as in the tar macadam. (2) The wearing surface 2½-in. thick is composed of a mixture of broken stone ranging in size from 2-in. to an impalpable powder mixed with sand in certain proportions to as far as possible eliminate the voids. This stone is mixed, preferably in a rotary mechanical dryer, at a temperature of about 250° Fahr., and passed through a revolving screen, to enable proper proportioning and measuring of the several sizes. Each grade of the mineral aggregate selected and mixed is then thoroughly coated and surrounded with another patent bituminous mixture so as to fill all the voids in the mineral aggregate. The whole mixture is hauled to the street in its heated condition, and there spread on the prepared foundation to such depth that after thorough compression with a steam roller it shall have a depth of 2½ inches. After the rolling of the wearing surface is spread a thin coating of patent drying bituminous flush coat composition, the purpose being to thoroughly fill any unevenness or honeycomb which may be on the surface of the coarser mixture. Fine sand is then worked or "squeezed"

into the surface until all surplus flush coat composition has been taken (or dried) up by it, and all surplus sand then removed with stiff brooms. A thin layer of stone chips, depending in coarseness on the rate of grade of the street, is then rolled into the surface for the purpose of giving a surface which will not be slippery.

In all tar macadam (bituminous) work it is very essential that each layer be kept free from dirt and moisture so as to ensure a good bond between layers.

The bituminous pavement is claimed to be more durable in every way than the ordinary tar macadam, but has a less depth of stone, viz., 6½ inches as against 8 inches, and only 2½ inches of bituminous wearing surface compared with 4 inches in the tar macadam. Time only and the local conditions of travel will decide which is the better form of pavement.

Brick.

Brick pavements have not taken a strong hold on public favor on residence streets, because of the increased noisiness under traffic, but brick has been used extensively in paving business streets with heavier traffic, and for paving street railway track allowances. Some years ago brick was laid on old macadam (broken stone) and gravel foundations, owing to the low costs, but this proved to be a very unsatisfactory method of construction, as uneven settlements caused the pavements to become uneven and rough, and consequently more noisy, and also increased the effects of the traffic on the wearing surface of the brick. Since then, however, concrete foundations only have been used 4 in. in depth on residence streets and 6 in. on business streets. The concrete is similar to that described for asphalt. About five days after the concrete has been laid a sand cushion is placed on the concrete foundation of such a depth as will be 1½ in. after the brick are thoroughly bedded in place. This sand should be clean and not too sharp, as a softer sand will bed more firmly and remain more compact. The sand should be spread to such a depth that in drawing the template (cut to the exact crown of the finished roadway) over it there should be always a surplus, the object being to secure a uniform amount of compression of the sand cushion. Before laying the brick a line of one-inch boards are placed edgewise along each curb to provide for the expansion joints at the curb. In laying the brick two methods are used, one in which the brick are laid diagonally at an angle of about

30° with a line at right angles to the curb, the claim being made that the increased surface of the brick offered to the traffic increases the durability and lessens the noise; in the other method the brick are laid at right angles with the curb and is much preferable for the following reasons: Affords a better foothold for horses; experience has shown that the noise and wear are not appreciably greater than with the other method; the expense of cutting at the curb and the waste of brick is much less and consequently less expensive. The brick are laid in parallel rows, care being taken to not get the brick too close so as to permit proper grouting. After a considerable stretch of brick work has been laid, and the culls removed, the brick are first swept off clean and thoroughly rammed with 80-pound wooden rammers, having a face 12-in. x 12-in. an inch hardwood board being used on the brick to ensure an even surface after ramming, and then the surface is thoroughly rolled with a roller of at least 5 tons weight, all damaged and chipped brick being removed as the rolling progresses, and the surface rolled until it conforms to the proper cross-section, and is even, smooth and compact.

After being cleaned off the surface is well sprinkled with water and the first coat of grout filling applied. This consists of one part of approved cement to two parts of approved clean, sharp sand, thoroughly mixed dry and then mixed in small quantities with sufficient water in a suitable mixing box so as to give a grout of proper fluidity when thoroughly mixed and stirred. The grout is then instantly applied to the pavement and at once swept into the joints with proper brooms. This coat of grout is intended to fill one-half the depth of the joints. Before this has had an opportunity to become set, a second coat of grout consisting of two parts of cement to one of approved sand is applied in the same manner as the first, the only difference being that the grout of this second coat should be thicker. The second operation should be repeated until all joints are full and a surplus of grout is shown on top of the brick, when an even layer of clean sand, not more than $\frac{1}{4}$-in. in thickness, is spread over the surface and the street closed to all traffic for from 5 to 7 days, according to weather conditions.

After the grouting has set sufficiently to permit the removal of the 1-in. boards along the curbs without loosening or disturbing the bricks, the boards are removed, and the space carefully filled with heated liquid paving pitch, this elastic material acting as an expansion joint. In several American cities the experiment has been tried

of also providing expansion joints every 50 feet along the street, but experience shows this to be unnecessary and in some cases a serious detriment to the stability of the pavement.

The requirements for our No. 1 Paving Brick are as follows: Bricks must not be less than 2½-in. x 8½-in. x 4-in., and must be even, regular and uniform in size and shape, and as nearly as possible alike in color and appearance throughout. The brick throughout must be free from cracks, checks or any imperfections, which, in the Engineer's opinion, may unfit them for use in the work; they must also be hard, tough, uniform in texture and thoroughly annealed throughout.

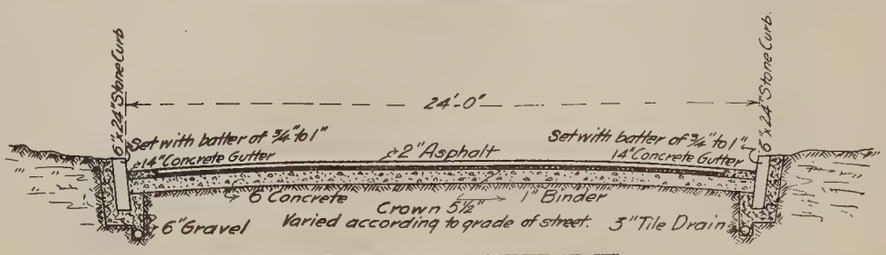
The contractor must submit sample bricks to the Engineer for his approval at least three days before hauling any to the vicinity of the works. The bricks must be capable of standing the following tests: —Abrasion: Any six bricks must not lose more than 18 per cent. of their weight after 1,000, nor more than 30 per cent. after 2,000 revolutions, when tumbled in an iron rattler, revolving at the rate of 26 to 30 revolutions per minute, which rattler contains 100 cast-iron cubes (with corners rounded to about ¼ in. radius), weighing about eight pounds each.

The rattler shall be 24 in. in diameter by 36 in. in length, with 4 iron bolts, each ¾-in. in diameter, projecting 1½-in. on the inside surface of the rattler; these bolts are to be placed in the two opposite staves (two in each), staggered in such a manner as to prevent the cubes and bricks from sliding instead of tumbling. Absorption—A piece broken from the centre of any brick, not more than ¾-in. in thickness, and from 60 to 120 grammes in weight, is to be thoroughly dried and then immersed in water; after being in water for six hours, the increase in weight must not exceed two per cent.

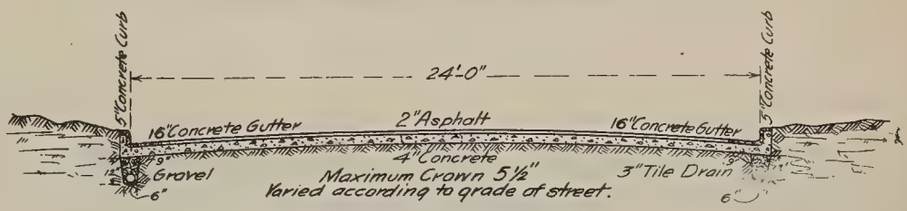
Macadam Roadways.

We divide these in three classes, viz., 1st, 2nd and 3rd. The 1st class macadam consists of a Telford foundation of 6 or 8 inch stone blocks, securely bedded on a compact foundation, the interstices being well spalled up with stone chips driven in with a light stone hammer. On this foundation a layer of approved broken stone, not more than 5% of which shall be less than 1¾-in., and no particle of stone shall be more than 3 inches in length or breadth, is spread and raked to present a perfectly uniform surface, and which when thoroughly rolled is 4 inches in depth. This course is blinded with a fine gravel, or a coarse sand which is well washed into the stone and thor-

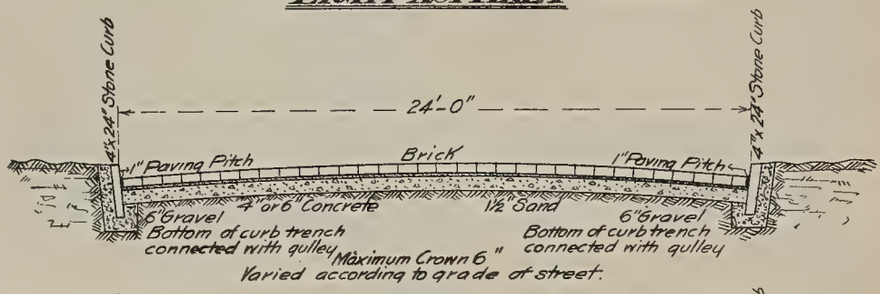
STANDARD CROSS-SECTIONS
PAVEMENTS AND SIDEWALKS
City Engineer's Office — Toronto Ont.
Scale of Pavements; 1" = 1/4"



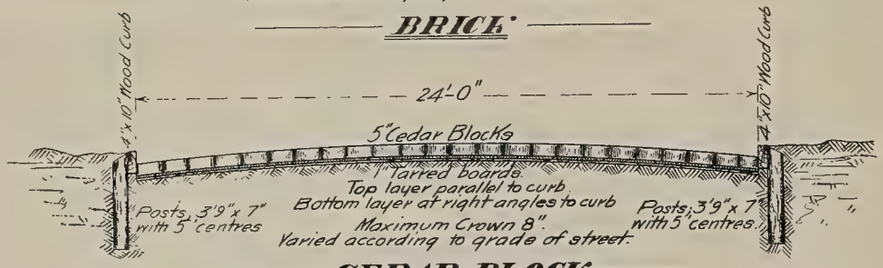
HEAVY ASPHALT



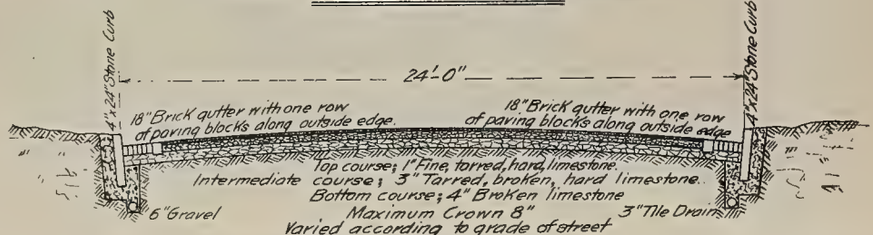
LIGHT ASPHALT



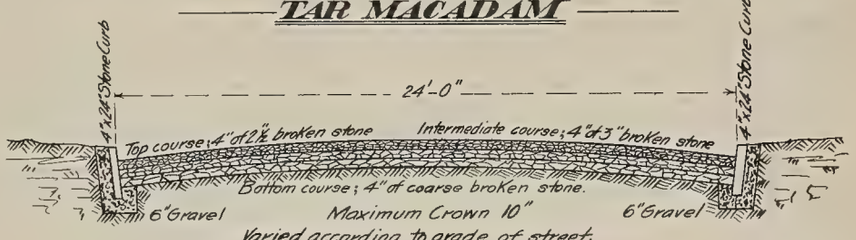
BRICK


4"x10" Wood Curb
24'-0"
4"x10" Wood Curb
5" Cedar Blocks
1" Tarred boards.
Top layer parallel to curb
Bottom layer at right angles to curb
Posts; 3'9" x 7" with 5' centres
Maximum Crown 8".
Posts; 3'9" x 7" with 5' centres.
Varied according to grade of street.

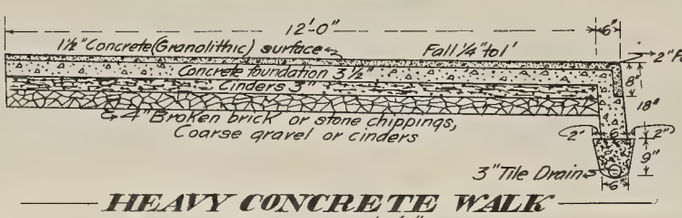
CEDAR BLOCK


4"x24" Stone Curb
24'-0"
4"x24" Stone Curb
18" Brick gutter with one row of paving blocks along outside edge.
18" Brick gutter with one row of paving blocks along outside edge
Top course; 1" Fine, tarred, hard, limestone.
Intermediate course; 3" Tarred, broken, hard limestone.
Bottom course; 4" Broken limestone
6" Gravel
Maximum Crown 8"
3" Tile Drain
Varied according to grade of street

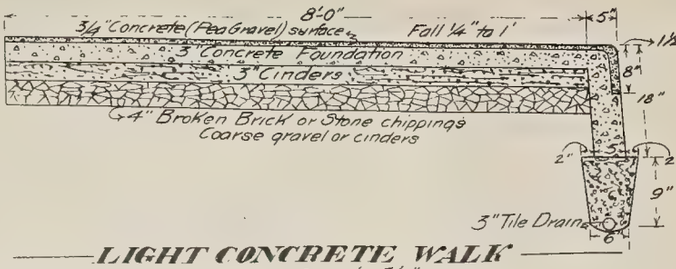
TAR MACADAM


4"x24" Stone Curb
24'-0"
4"x24" Stone Curb
Top course; 4" of 2 1/2" broken stone
Intermediate course; 4" of 3" broken stone
Bottom course; 4" of coarse broken stone.
6" Gravel
Maximum Crown 10"
6" Gravel
Varied according to grade of street.

MACADAM



HEAVY CONCRETE WALK
Scale; 1" = 1/2"



LIGHT CONCRETE WALK
Scale; 1" = 1/4"

Chas W. Dell
Roadways Engineer
January 20th 03.

M.A. Stewart
17.1.02

oughly consolidated by rolling. The top course of approved granite or trap, the particles to be as nearly uniform in size as possible, not more than 5 % being less than 1½-in., and no particle being more than 2½-in. in length or breadth, is then laid and raked to ensure a uniform even surface which, when blinded and thoroughly rolled, shall be 4 in. in depth, and conform to the lines and grades shown on the cross-section drawing. The blinding is done in the following manner: A layer of good, clean, coarse sand is evenly spread over the whole surface and flooded with water to carry the sand into the voids of the stone surface, and the rolling, with a 12-ton steam road roller, carried on at the same time. Where settlements occur, new stone and sand are added until the surface is even, uniform, thoroughly hard and compact, and conforms to the required cross-section. A thin layer of stone screenings and limestone dust is then spread evenly over the surface and permitted to work into the surface of the street by the effects of the traffic. Before opening the street to the traffic, the surface should be allowed to dry out and become solidified for two or three days, as otherwise it cuts up badly. Even under favorable conditions, however, there is at first a tendency for the stone to loosen up, but this soon disappears and we find the limestone dust combines with the sand to make a very hard, compact surface filling.

The 2nd class macadam consists of a broken stone foundation 4 in. in depth after rolling, of hard suitable stone, which we specify as coarse, broken stone, and in which we permit particles as large as 5 inches in length or breadth; this is thoroughly rolled (no blinding being used) into the sub-grade, and the two courses of broken stone laid as described for the 1st class macadam.

The 3rd class macadam consists of two 4-in. courses of broken stone, laid as described for the 1st class macadam, the only difference being that we permit of larger particles of stone in the bottom course.

The 1st class macadam is laid only on business streets, and streets leading from freight sheds, warehouses, etc., where there is very heavy traffic. The 2nd class is laid on the better class of residence streets, with moderately heavy traffic, and the 3rd class on outlying streets or on streets with light traffic only.

The soil in Toronto is such that tile drains under the curbing are not required except in special cases, and the accompanying sheet of standard cross-sections of our various pavements indicates clearly the use of the tile drains and also the necessary construction and details of stone, concrete and wood curbing.

ADDRESS OF W. T. JENNINGS, M.I.C.E.

[Extracts from the address of W. T. Jennings, M.I.C.E., Chairman of the Board of Examiners in Engineering, Toronto University, to the students of the School of Practical Science, Toronto, when assembled at their Annual Dinner on the twenty-eighth of November last.]

The young man of to-day who desires to obtain a liberal education with the object of advancing through "life's rugged way," in one or other of the numerous branches of Science, has many advantages which were not obtainable, at least in a complete and satisfactory manner, some thirty years ago, when Institutions like the School of Practical Science, with its admirable staff, commodious quarters, and up-to-date equipment were not known in this country.

To-day an earnest student may at a reasonable expense be advanced from the humble country schoolhouse through the various educational steps leading to and through the University, which crowns his work by conferring on him the coveted degree or "hallmark," so necessary for success in this age of "professional specialties."

The student in Engineering has doubtless in many cases had his thoughts turned in that direction by observing the success of those who have preceded him, and he frequently enters the School of Science without having any defined course mapped out. However, after a time he begins to know himself, and, if he finds the general course of study congenial to his mind, he takes form and resolves on the particular branch of the profession of an Engineer most in keeping with his inclinations, be it Hydraulic, Mechanical, Marine, Electrical or Mining, or a suitable combination, such as Mechanical and Electrical, Mining and Metallurgical, and so on.

If he be rightly seized with the importance of his decision, as being a large factor in his future, he will bend his whole attention and energy to the mastery of the theoretical and, as far as time and opportunity permit, the practical features of his choice.

On the other hand, should he find after a fair trial that he has erred in his selection it is better that he at once abandon his course, than attempt to drag along in an uncertain half-hearted way, as failure can only result.

Diligence in study and attention to work must be continued long after college days are successfully over—in fact, we are students almost all our days—but the "how long" depends largely on the individual, not only on his skill as an Engineer in planning works, and seeing that they are successfully and economically carried out, but in observing and grasping opportunities apparent to his trained eye and mind.

Of all the professions that of an engineer calls for the highest standard of honesty in word and deed, as much often time hinges on his opinion, or to the successful execution of undertakings—be they gigantic or petty in character—which have been placed in his hands.

His sense of honor and right should be of the highest order, and he should be able to "say, no" emphatically to all schemes of a doubtful character.

To his client he must be thoroughly loyal. To his fellow practitioners he should display brotherly love instead of the reverse, as unfortunately, occurs in all professions.

To the young engineer I would say—Do not imagine that because you are a college graduate you know yourself and your profession sufficiently to warrant the taking up of important work without the advice and guidance of your seniors in years and general experience, as there are features other than those of a theoretical nature and which can only be acquired by experience; such as the commercial aspect—the location of a railway line or power site, the detailed design, the actual construction and the judicious use of materials, etc.

Do not give an engineering opinion on hearsay or casual remark, and be slow in venturing one at all until you are in possession of facts sufficient to enable you to do so in a scientific and creditable manner.

In the matter of monetary compensation. It too frequently happens that the return for faithful and successful service is far below a just sum, and this result is largely attributable to the engineers who, in many cases, allow themselves to be led away by "promises," or by the fear of losing a fee on a contemplated work which they think will be a lasting advertisement.

Thus do they depreciate their professional value and importance in the minds of clients, be they individuals or companies, and until these conditions change, by the united practice of a recognized code, the Civil Engineer will not be acknowledged and accorded his just standing, as a demonstrator of the most learned profession.

STEEL HIGHWAY BRIDGE WORK IN ONTARIO.

E. H. Darling, '98.

In addressing this informal paper to the members of the Engineering Society, the writer's desire is not only to make it interesting to those who intend to follow the profession of Bridge Engineering, but to more especially draw the attention of a much larger number,—who, as Municipal Engineers, etc., will have indirectly more or less to do with the building of highway bridges,—to a subject, which on account of its recent development and supposed insignificance, does not receive the study it ought.

Scores of steel bridges are now built every year in Ontario, and the number is rapidly increasing every year. We are nearly past the experimental stage, and it has become a duty of Civil Engineers in general to have some definite practical knowledge of the subject. We shall not waste time in going over any theory, which may be found in books, or which will come to you in your studies, but shall discuss a few practical conclusions which engineers have arrived at by observation.

In limiting the subject to Ontario bridge work it is hoped to make the paper of more practical value to the Society, especially as most literature on bridge work is usually very general, and there is little, if any, which deals with work in this Province, in particular.

The history of steel highway bridges in Ontario would not take long to tell. Fifteen years ago, and perhaps less, what metal bridges there were, were made of iron, and it has only been in the last few years that the great improvement in the manufacture of steel and the reduction of its cost, has enabled it to drive iron entirely out of the field. In 1887-8 there was a paper read before the Society which contained this statement, which at that time was perfectly true.

"Of late years steel has been considerably used in bridges. At present, however, the opinion of leading professional men is averse to using it altogether in place of iron, preferring the less strong but

better known metal for tension members, or those subject to alternating stresses, and using steel only in compression members and in webs of plate girders." (Society Papers Vol. 2, p. 44).

Four years later quite an interesting discussion arose amongst the members of the American Society of Civil Engineers over a statement made by a prominent Bridge Engineer, to the effect "that in the near future bridges would be built entirely of steel." His expression "in the near future" came in for considerable mild sarcasm, for even at that date—1891—there were large railroad companies who never used a pound of steel in their bridge work, and the most advanced only in less important members.

For us young graduates, who, when we entered the profession, found the above prophecy completely fulfilled, it is hard to realize that structural steel has become popular so recently. To-day engineers prefer to use steel in almost every instance rather than iron. Iron has now become the "uncertain material" although some still use it for loop bars and such members which require welding, as it is easier to weld than steel, and for field rivets, because iron rivets are easier to drive and are not so liable to be injured when driven at a low temperature.

The reason for this change in opinion is to be found in the great improvement made in the manufacture of steel. Now every possible care is taken to produce a metal perfectly uniform in its chemical and physical properties, and considering the great quantities made, the results obtained are remarkable. But the great feature in the manufacture is—that the Engineer may have the satisfaction of knowing exactly the material he is using. A piece of steel which he uses in certain members can be traced back by means of carefully kept records to the particular shipment of ore from which it was made, if necessary. He can obtain chemical analyses of the ore, and the "pig" smelted from it. Another analysis after it is converted into the steel ingot, and after it is rolled into shapes (all the time under careful inspection) he can have tests of its physical properties before he uses it. Nor need his inspection stop there, for when the material is worked up into the structure at the bridge shops, every piece may be carefully watched for flaws or bad workmanship, and every rivet "tapped" to see that it is driven tight. If, when the whole structure is completed, it fails, the Engineer can have the consolation that it

was more likely due to his bad design than to any defect in the material.

After the usual process of education, the rural municipalities and corporations of Ontario are beginning to see the economy in replacing their worn-out bridge with steel structures, and thousands of dollars are now spent annually for steel bridges all over the Province. The class of structures they replace are usually a combination of wood and iron—often very ingenious in design and in some cases iron bridges which have outlived their usefulness.

Unfortunately a steel bridge does not necessarily mean a good bridge, and it is sad to say that highway bridge work in general is not up to the standard which the best authorities set for it. This is in many cases due to a false notion of economy, but sometimes the ignorance of the Town or County Engineer is more responsible for it than the parsimony of his client. The pioneers in steel bridge work may be forgiven many of their mistakes, for they were working in a new field with a new material, but while it will be many years before the disputed points in bridge work are settled, still there is a generally recognized standard practice which it is the duty of every Engineer, who has to do with bridges, to know.

The best examples of highway bridge work are to be found in the large cities, as such work is usually in charge of expert Engineers, and more money is put in it. But we cannot expect the rural highway bridge to come up to the same standard any more than we can expect the county roads to be paved with asphalt. The principle which is to guide the Engineer is that he must endeavor to get the highest efficiency possible from the money invested. So if by increasing the first cost of a bridge by a small per cent. he can get a much better bridge, and one which will last longer, he is wasting money not to do so. This is one of the first general principles of engineering, and it will decide in the first place what material the bridge is to be made of. But when it decides in favor of a steel bridge it should be carried to its logical conclusion, and what would otherwise be a first class bridge should not be spoiled by trying to save a little in its first cost.

Keeping this thought in mind let us examine the common practice in steel bridge building in Ontario and see in what way a little more money invested could greatly improve the structures, or how the money which is spent could be spent to better advantage.

For spans up to thirty feet rolled beams are used, forming a simple beam span. From thirty to ninety feet some type of riveted pony truss is used, built up of angles and plates, usually a Warren truss with tee chords. At the panel points the floor beams—rolled I-beams—are riveted, and the truss is supported laterally from these by knee braces of one kind or another. The floor beams, of course, carry the joists (which are frequently I-beams), and these carry a plank floor.

Above ninety feet overhead bracing may be used with economy, giving a "through bridge." These are either riveted or pin connected trusses, and the details vary with the different types. In the riveted spans, all connected are rigidly riveted together with the exception perhaps of the lateral rods, which are sometimes made adjustable. In the pin spans not only are all the joints of the trusses pin connected and lateral rods adjustable, but they also have adjustable counter-braces, and the floor beams are suspended from the bottom chord pins. The top chords of both types are of built-up channel section, but while the tension members of the pin span are of round or rectangular cross-section, those of the riveted span are built up of angles and plates. The laterals also are often made of angles with riveted connections. The result of these differences in construction is apparent. The riveted span is stiff and rigid as a whole, and in all its parts. Pin connections on the contrary allow motion. The tension members are unable to resist vibration laterally, and adjustable members get loose and fail to act. This accounts for the excessive vibration and rattle which arises when a load is passed rapidly over a bridge of this design.

The types of trusses used in spans from ninety feet up to say three hundred feet are very uniform. Pin spans are always Pratt trusses with a single web system, and the riveted spans are a double intersection Warren truss. Some riveted Pratt trusses have however been put up. The longer spans usually have inclined top chords.

Such is the present practice, and it is a great improvement on that of a few years ago, as an examination of the existing iron bridges would clearly show. It is not uncommon to find pin connected pony trusses for very short spans much less than ninety feet, and longer bridges with double or triple web systems.

The riveted Warren truss is a great improvement on short pin spans, and when properly designed with steel joists and stiff laterals

it gives a stiff neat bridge, and is cheaper than any other type for spans from fifty to ninety feet. Below fifty feet the trusses become too light to make a good bridge unless a great excess of metal is put in it, and for spans under this length it would be much better to use plate girders. The only objection to plate girders is the difficulty of handling them and teaming about the country to remote bridge sites, when they get over 30 feet in length. So it is often more convenient to use a small truss for spans under this length, but the resulting bridge is much inferior to a good plate girder span.

Riveted spans are so superior to pin spans that they should always be used for spans under 250 or 300 feet. Railroad companies are now building riveted spans up to 180 feet—the Dominion Government specification puts the limit at 200 feet. As mentioned above, the great objection to light pin spans is that they are not so rigid as the riveted, they vibrate a great deal and consequently have more wear, get loose and out of adjustment, and require much more care to keep in order. Besides, however carefully a pin span is built there is always a great deal of uncertainty as to the distribution of the stresses, caused by slight errors in the length of members, play in pin holes, the adjustment of counterbraces, etc. They will not stand the rough usage a riveted span will, and if one member becomes injured the whole span falls. Many cases are known where riveted spans have stood long enough to be repaired after an important member has been destroyed. The traction engine is very hard on pin spans unless they have a stiff end bottom chord, such as railway pin spans always have.

The chief advantage of a pin span is that it is easy to erect, and is economical in material. This is especially the case for spans between 90 and 150 feet long, for from the nature of its makeup a riveted span of this length requires a great excess of material to make a good bridge.

All parts of a steel bridge are now reduced to as few in number and as simple in form as possible. Instead of using a double system of light web members such as we see in iron bridges still standing, a simple system is used and made heavier. This principle is carried out through all parts of the bridge. Apart from the apparent economy in material resulting from this massing it into heavy members, the great advantage is that it does away with a great deal of ambiguity of stresses and allows the use of a smaller factor of safety.

Many bridges might be improved by using stiff lateral bracing instead of adjustable rods. It may not always be as convenient to connect the stiff bracing to the truss, and this detail must be carefully watched or the result may be worse than the rods.

At present very few highway bridges are made with an end floor beam to carry the joists on the abutment—the ballast wall being built up to take the end of the joists. Very seldom is a strut of any kind put across between the trusses at this point. This may be very economical, but it cannot be called good practice, especially when the spans get up to 100 feet in length. It is impossible to have the end bottom laterals (the most important in the whole bridge) tight by this construction,—or rather want of construction,—unless the very uncertain action of the anchor bolts is depended upon to take the stress.

Besides this violates another principle of first class bridge work which is,—that the steel work should be complete in itself, and independent of other materials. This principle carried to its limit, as it is in first class work, not only requires steel floor beams, but also steel joists, solid concrete or ballasted floor, steel hand-rail, and the exclusion of wood, or wood blocking, or anything which would require frequent renewing.

The buckle-plate or expanded metal floor has been used in many bridges in or near large cities, but with these exceptions plank is used for flooring.

One of the drawbacks to the use of steel is the difficulty of preventing it from rusting. Under ordinary atmospheric conditions it readily oxidises, and unlike such metal as copper or silver, a coating of oxide or rust does not protect the metal. On the contrary, the rust once formed acts as a carrier of oxygen to the metal beneath. This is how rust eats into steel, causing that " pitting " effect.

The chemical action which goes on is expressed by the following equations:—

(1) $\quad Fe + H_2O + CO_2 = FeCo_3 + H_2$

(2) $\quad 2\ FeCO_3 + O = Fe_2\ O_3 + 2\ CO_2$

All that is necessary is the presence of moisture and carbonic acid gas. The carbonic acid acts on the iron, forming a carbonate. This carbonate absorbs oxygen from the air, and forms the oxide or rust, liberating the carbonic acid to repeat the operation.

To prevent this, steel is always given a coating of some kind of paint, and there are dozens of patent preparations all warranted to do this. There is a great deal of literature on the subject in engineering periodicals by writers supporting one brand or another, quoting tests to back their claims, which claims are often very different. It will take some years to settle the question, but at present the best authorities have reached the conclusion that the value of a coat of paint depends more on the way it is applied, than on the paint itself. Not that the kind of paint makes no difference, for it is of great importance, but there are several different kinds, all of which give good results when properly applied, and very poor results when care is not taken.

The most popular paint consists of linseed oil and some inert pigment such as red lead, iron oxide or graphite. The linseed oil gives a tough, thick coat which is waterproof and air tight, and the pigment gives it durability. It is rather difficult to get these ingredients pure, and free from adulteration, and the impurities which are found in them are very injurious to steel.

It is common practice to mix the paint with some such thing as turpentine or benzine to thin it, and to make it dry quickly. The result is that the quality of the coat is greatly injured, it being thinner and more brittle. When linseed oil dries slowly it gives a tough elastic coat, and its adhesion to the steel will not be affected by a change in temperature. Raw oil dries slower than the boiled, so it is the better. The condition of the surface to be painted is of the first importance. It should be thoroughly cleaned from all scale, rust, oil, grease, moisture and dirt of any kind. Stiff wire brushes should be used for this purpose, and paint should not be applied until the color of the metal is everywhere visible. If rust is left on, the steel will go on rusting under the paint. Scale and dirt prevent the paint from sticking and cause it to peal off. Moisture in any form is very injurious and it is very hard to exclude. It forms a coating on the steel and is often in the oil of the paint. It not only prevents the adhesion of the paint but it starts the rust.

The paint should be used as fresh as possible, be carefully mixed and kept well stirred. It should be applied with the best paint brushes and each coat should be as heavy as practicable. The first coat is the most important, for if it is poor the next coat will not stick.

Such are the requirements of good painting, but it must be borne in mind that no paint yet invented, no matter how carefully applied, is a perfect protection for more than a few years. Its life depends on the conditions to which it is subjected. On overhead bridges where it gets the exhaust of locomotives, it will not last more than a few weeks, while under favorable conditions, it may last ten years. Steel work exposed to the weather should be gone over very carefully at least every two or three years. A careful inspection after the first year would be of more value than one later.

If the bridge is going to be carefully looked after and repainted frequently, it may not pay to take such extreme care of the first coat. The great fault is that highway bridges are not carefully looked after, and from the time they are erected until something gives out, no attention is paid to them. Many municipalities will be very much surprised in a few years to find that the "permanent" steel bridge which they put up a few years ago is all rusted out, and needs rebuilding. They will then come to understand that a steel bridge must be given more care, or be designed to withstand rust as well as to carry its loads.

This brings us to the consideration of a second point which should be given more attention. In all small highway bridges the maximum stresses produced by the loads are never very large, and are often only a few thousand pounds. To carry these stresses, according to the regular rules of design, will require such a small section of material that the smallest standard shapes are used so as not to put in any more steel than the stress actually requires. Hence it is not unusual to find in bridges metal $\frac{1}{4}$" thick, and even 3-16" thick. Material as thin as this presents a very large surface to rust compared with the amount of metal in it. For example,—if a 3-16" plate rusts 1-32" deep all over, 33% of the original section is gone.

Besides this, the use of thin material has another very bad point which is very seldom taken into consideration. As such material has always to be rolled at a much lower temperature than heavy material, it is usually very hard and brittle. Consequently, it is very easily injured by careless work and handling, and may be of little value even before the rust starts.

From all this it is evident that it is not economical to use material below a certain size and thickness. For railroad work engineers fix this at $\frac{3}{8}$ of an inch, and the smallest sections for main members is

3 x 2½ x ⅜". For highway work the limit is 5-16", and the smallest sections 2½ x 2½ x 5-16 angle, and 5" channel. This, of course, does not apply to any ornamental iron work such as lattice handrail, for here, besides being useless, the heavy material would look clumsy, and spoil the effect.

It is often the case in highway bridge work that what would otherwise be a first-class bridge, is spoiled for the want of a little more material, the extra cost of which would be but a small per cent. of the total cost of the bridge. It is very seldom in short spans that the substructure does not cost as much as the superstructure or steel work. Again, the cost of the raw material in the superstructure may be taken as half of this. In other words—the total cost of a bridge may be roughly divided as follows—50% for the substructure, 25% for steel and 25% for work on the steel. Now, the amount of steel in the bridge might be increased as much as 25% without altering the other two quantities, and this would mean an increase of only 6¼% on the total cost of the bridge to the purchaser.

The bridge company cannot be blamed for making the steel work as light as the specifications will allow, because the increased weight means 12½% of their contract, for they have to enter into competition with the other companies with the almost certain knowledge that five dollars difference will lose them the contract, regardless of the relative value of the designs.

There may be very few members of this Society who will make bridge work their special study, but there is no doubt a much larger number, who, acting as town or county engineers, may be called upon sooner or later to purchase a bridge and oversee its erection. To these a few hints from the contractor's point of view, may be helpful in securing a good bridge, and save them from making those blunders which add so much to the load of worry of the poor draftsman.

In the first place, forego your natural desire to design a bridge all by yourself. There are so many things to think about that even quite experienced men sometimes overlook important details. If, however, you did get a design which would stand up, there are great chances that no bridge shop could make it, for it is the easiest thing in the world to design something that cannot be made from mechanical reasons. The bridge company's engineer knows what material they have in stock, and what sections they can get quickest from the rolling mills.

He knows what sections work together and make the neatest connections. He carries in his head a score of facts which enable him to cut down the cost and better the bridge. The draftsman who makes the drawings is accustomed to trace the action of stresses through complicated details, understands the properties of the materials used, and knows where to be lavish with it, and where he can save.

For many such reasons as these, municipal engineers of the class to which I am referring, are not expected to make their own designs for bridges, as perhaps they once were. His work is to give the length of clear span, and the general dimensions, such as width of roadway and sidewalk, clear head room, &c., the heaviest load the bridge will be expected to carry, and all information of a local character, as distance of site from railway station, height of floor above high water, the kind of banks and river bed, and the depth and speed of the river. He has then also to "specify" the material to be used, the stresses it shall carry, and the treatment it shall receive. In other words, draw up specifications for the bridge. Better still, he can adopt any one of the many standard specifications and require the work to be done according to them. The Government Department of Railways & Canals have standard specifications, which should be used for all public work. These are very complete and are kept up to date. They cover all such points mentioned above, as paint, minimum thickness, &c., and a bridge built to them will be first-class.

The engineer should study these specifications carefully, and call for tenders requiring that all work comply in every respect to the Dominion Government specifications of the latest date. He should then see that they are carefully carried out. This puts all parties tendering on an equal footing, and is much fairer and more likely to produce a good bridge than leaving it to their individual specifications. With the tender should be required a strain sheet with the figured stresses of every member marked, and the section of material proposed to be used. It is not reasonable to ask for detail drawings with the tender, but the successful bidder should be required to submit his detail drawings to the Engineer for approval before doing any work in his shops.

In accepting a tender it should be remembered that the lowest bid is not always the best. Other questions should be taken into consideration, such as the general design, the responsibility of the bidder, time of delivery, &c.

After the tender is accepted it is the Engineer's duty to check over the strain sheet to see that the specifications are adhered to, and later, when the detail drawings are submitted they should be checked in the same way, with special attention to the strength of all connections. He should know enough about bridge work to do this, or he should not be in charge of the work. If his figures do not agree with those of the contractor, he should not be afraid to speak about it, for if he is wrong he will most likely learn something he did not know before.

It would hardly pay to employ a regular shop inspector to watch the work on a small highway bridge. The only way to do is to have carefully drawn specifications, and give the contractor to understand from the start that the work will not be accepted unless it is done exactly as called for.

Ornamentation of highway bridges would be a waste of money, but this is no excuse for poor workmanship. First class work should be insisted upon, and such things as bad rivet heads, open joints, rough projecting edges or corners, uneven painting, &c., should not be accepted. If the bridge is finished in a proper workmanlike manner it will have ornamentation enough from an engineering point of view.

The suggestions offered in this paper will seem to those who have not studied the bridges of Ontario as self evident, and scarcely important enough to form the subject of a paper. It is, perhaps, because of their supposed unimportance that they continue to be overlooked in a large percentage of the bridges put up. The writer hopes that in a few years his paper will become out of date, as the one referred to above, and that the time will soon come when the money of the municipalities will be spent to more advantage than it is in some cases at present.

As a writer says in a recent paper read before the American Society for the Advancement of Science (see Eng. News, Vol. 48, p. 43).—"The application of scientific principles to the construction of bridges is more complete to-day than ever before. This statement applies to the specified requirements which the finished structure must fulfil, the design of every detail to carry the stresses due to the various loads imposed, the manufacture of material composing the bridge, the construction of every member in it, and finally the erection of the bridge in the place where it is to do its duty, as an instrument to transportation."

SEWERAGE OF A VILLAGE.

R. McDowall, C. E., O. L. S., A. M. Can. Soc. C. E.

SURVEY AND LEVELS.

The first work an engineer must perform in undertaking to design a system of sewerage for a town or village is to survey the streets, blocks, railways and bridges, and also the watercourses, creeks or rivers, mill ponds, or any other natural features found in the said corporation. The next is to make a plan of the same on a scale of at least 200 feet to an inch.

After completing this plan his next duty is to take the levels of the streets, &c. Before beginning levels it is necessary to fix upon the outlet of the sewerage system. To prevent any danger from sewerage contamination, an outlet into a large body of water or into a swift running stream is requisite. In many cases the outlet is into a lake, as at Toronto, Hamilton, Kingston, Barrie and Owen Sound; in others, into a swift, powerful river as at Detroit, Buffalo, Montreal, Niagara Falls, and Sault Ste. Marie. In the case of Chesley, Ont., for example, the easiest outlet for construction would have been into the mill ponds; that, however, was out of the question as the sewerage would accumulate and poison both water and air. The outlet for this system was fixed below the lower mill dam into the north branch of the Saugeen River, which is here a very wide stream two feet deep and sixty feet in width. The nearest mill pond on this river below Chesley is eight miles distant, so that the stream has ample time to purify itself.

Levels are always fixed by a certain datum line, and the datum fixed upon in this case was 100 feet below the level of the bottom of the river at the lowest outlet.

Levels.—As sewers are almost always laid down the centre of the street, the levels should be taken there; unless there is an abrupt

change of grade, it is generally sufficient to take them at distances of one hundred feet, and at all points where streets intersect. Bench marks on some permanent door-sill, window-ledge, hydrant, or cement concrete sidewalk should be levelled and marked at all street intersections to serve as convenient data for future levels. Levels should also be taken of all cellar floors, if cellar drainage is requisite, as is generally the case.

DESIGN.

After taking all surveys and levels, the direction, grade, and size of the necessary sewers for the proper drainage of streets, cellars, bath-rooms and closets must next be designed. The great objects to be aimed at in the design are, on the one hand, to secure proper drainage, and on the other, to keep down the cost; in a word, to give the best value for the money expended. This Scylla and Charybdis, however, meets the engineer in all designs.

Length.—The distance from the head of a sewer to its outlet should be as short as possible. A straight line between the two points would be the cheapest, but if it did not serve the purpose it would be useless; as street and house drainage is requisite, it is necessary to carry the sewer along the two sides of the triangle, that is, along a street to its intersection with another when it will turn the corner. Here length has to be sacrificed to necessity.

Direction.—For economical purposes, the direction of the grade of a sewer should be the same as that of the street. For instance, if a sewer follows the grade of a street having a fall of 1 foot in 100 feet, its depth will be uniform throughout its length, whereas if it were to be built against the grade of the street its depth would increase 2 feet in every 100 feet; thus the amount of excavation would be greatly increased. Many cases, of course, arise in which it is necessary to build the sewer against the grade of the street, in order to obtain an outlet along another street, although, perhaps, by following a ravine in close proximity to the same street an easy grade could be obtained.

Grade.—The grade and size of a sewer are in a measure dependent on each other. To make a certain amount of flow, if the grade be small, the size of the sewer must be increased and vice versa.

Staley and Pierson in their "Separate System of Sewerage," give the following as minimum grades of sewers:—

6″	pipe 1 foot in	200	feet; a grade of	.50%
8″	pipe 1 foot in	280	feet; a grade of	.36%
9″	pipe 1 foot in	320	feet; a grade of	.31%
10″	pipe 1 foot in	360	feet; a grade of	.28%
12″	pipe 1 foot in	450	feet; a grade of	.22%
15″	pipe 1 foot in	600	feet; a grade of	.17%
18″	pipe 1 foot in	750	feet; a grade of	.13%
20″	pipe 1 foot in	890	feet; a grade of	.11%
24″	pipe 1 foot in	1,160	feet; a grade of	.09%

In the experience of the writer the above grades are too small to give good results, as even in greater grades the sewage is often stranded in the pipes. Baumeister, in his " Cleaning and Sewerage of Cities," gives the following empirical formula for the minimum grade of a sewer having a diameter of " d " inches. Minimum grade in per cent.

$$\frac{100}{5d \times 50}$$

This formula would give the following grades for sewers of various sizes:—

6″	pipe 1 foot in	80	feet; a grade of	1.25%
8″	pipe 1 foot in	90	feet; a grade of	1.11%
9″	pipe 1 foot in	105	feet; a grade of	.95%
12″	pipe 1 foot in	109	feet; a grade of	.91%
15″	pipe 1 foot in	125	feet; a grade of	.80%
18″	pipe 1 foot in	140	feet; a grade of	.71%
20″	pipe 1 foot in	150	feet; a grade of	.67%
24″	pipe 1 foot in	220	feet; a grade of	.45%

The minimum grades used by the writer are as follows:—

6″	pipe 1 foot in	125	feet; a grade of	.80%
8″	pipe 1 foot in	250	feet; a grade of	.40%
9″	pipe 1 foot in	278	feet; a grade of	.36%
10″	pipe 1 foot in	333	feet; a grade of	.30%
12″	pipe 1 foot in	400	feet; a grade of	.25%
15″	pipe 1 foot in	500	feet; a grade of	.20%
18″	pipe 1 foot in	625	feet; a grade of	.16%
20″	pipe 1 foot in	833	feet; a grade of	.12%
24″	pipe 1 foot in	1,000	feet; a grade of	.10%

Maximum grades should not exceed 80%, as the friction from particles of sewage in solution has a tendency to wear the invert or

lower part of the pipe; besides the speed of the flow leaves the sewage stranded.

The size of a sewer, as has been said before, depends on its grade, the amount of rainfall, and the amount of sewage. In a separate system of sewerage rainfall is not taken into account. A 6″ pipe is sufficiently large for house connections.

In designing a system the pipes should increase in size in proportion to the areas and population draining into them.

Rainfall.—Regarding rainfall, the following, for the years 1896, 1897, 1898, 1899, and 1900, taken from the record books of John McKenzie, the Government observer at Owen Sound, may be interesting.

The total rainfall during '96 was 30.03″, an average of .082″ per day, and .197″ for every day it rained. The total rainfall during '97 was 44.98″ an average of .123″ per day and .281″ for every day it rained. The total rainfall during '98 was 36.32″, an average of .099″ per day, and .265″ for every day it rained. The total rainfall during '99 was 44.15″, an average of .121″ per day, and .252″ for every day it rained. The total rainfall during '00 was 36.02″, an average of .099″ per day, and .32″ for every day it rained. The total average rainfall for the five years is .0932″, and .263″ for every day it rained.

The greatest rainfall in that period took place on the morning of Nov. 21st, 1900, when 2.54″ fell in 5 hours.

Sewers cannot be designed to carry off storm water at its maximum, for in such cases the sewers would be so large that in dry weather the sewage would be left stranded on the sides of the pipes.

According to Baumeister, the amount of rainfall that reaches the sewers varies with the condition of the soil or streets on which it falls, if on pavements a greater amount will reach them than on macadamized roadways.

In England an average of 50% of the rainfall reaches the sewers, in London 53 to 94%. From his experience 25% for villages, 50 to 70% for towns, and 70 to 100% for cities, would be ample.

The amount of sewage reaching the sewers depends upon the quantity of water used by each inhabitant.

According to J. T. Fanning, in his "Treatise on Water Supply Engineering," the amount of water used in the New England towns and cities per capita is as follows:—

10,000	population	35 to 45	gals.	per capita per day.
20,000	population	40 to 50	gals.	per capita per day.
30,000	population	45 to 65	gals.	per capita per day.
50,000	population	55 to 75	gals.	per capita per day.
75,000	population	60 to 100	gals.	per capita per day.

It can be safely assumed that a village having a population of eighteen hundred would use 25 gallons per capita per day, or very nearly 4 cubic feet of water.

DEPTH.—Economy demands that the depth of a sewer shall be as small as possible. There are several limitations as to their depth:—

(*a*) *Damage from frost in cold climates.*—In the opinion of the writer no properly ventilated sewer would freeze even if placed on top of the ground; the amount of warm air and water constantly pouring into it would prevent it. But the danger is not from frost inside, but from frost in the ground below and around the pipes heaving them; they should, therefore, be placed below the frost line, which in Canada is between 3 and 4 feet below the surface of the ground.

(*b*) *Danger of crushing from the traffic on the street surface above the pipes.*—The heaviest traffic on any street will be that of a steam roller, which weighs from 12 to 18 tons. There should therefore be at least from 3 to 4 feet of earth above the pipes to act as a cushion in preventing shocks. In Owen Sound there is a 9″ pipe three feet below the surface, which has stood the pressure of an 18-ton road-roller without receiving any damage.

(*c*) *The limit of rise between the outlet, and the cellar to be drained.*—The depth of any sewer at its upper end has to be sufficiently below the cellar to give a good fall to its lateral connection; and the sewer has to be carried at a proper grade from its outlet to that point; and this is the main condition in determining the depth.

FLOW IN SEWERS.

A pipe sewer reaches its greatest capacity of discharge when its depth of flow is some .93 of its diameter, and is then some 11% greater than when running full. Sewers should be proportioned

through the system so that the depth of the ordinary flow will be sufficient to prevent deposits. A certain amount of sewage which can be transported by a sewer of a certain size cannot as well be transported by one of a larger diameter. This is shewn by the following table taken from Staley and Pierson's "Separate System of Sewerage":—

Size.	Depth of Flow.	Velocity.	Discharge.
6″	3″	147	14.4 c. ft. per sec
8″	1.92	129	14.4 " "
10″	1.36	112	14.4 " "
12″	1.03	100	14.4 " "
15″	.75	83	14 4 " "

The following table illustrates the comparison of the velocity and discharge of pipe sewers when running at various depths:—

Depth of flow.	Velocity.	Discharge. in c. ft. per sec.
.067	.414	.0119
.1	.498	.026
.465	.602	.0548
.2	.6942	.0989
.25	.7698	.1497
.3	.821	.2072
.4	.9264	.3457
.5	1.0	.5
.6	1.0534	.6598
.7	1.0932	.8174
.75	1.0984	.8836
.8	1.1028	.9458
.8535	1.1010	.1.0009
.9	1.0918	1.0351
.933	1.0794	1.0479 greatest
1.0	1.0	1.0

The authors quoted above give the following formula for computing the velocity of any sewer: —

$$v = \frac{\sqrt{2gh.}}{\sqrt{1 + e + c\frac{l}{d}}}$$

in which h = head.
l = length of the pipe in feet.
d = diameter of the pipe in feet.

v = velocity per feet per second when running full.
c = co-efficient of pipe friction.
e = co-efficient of resistance to entrance.

$$c = .01439 + \frac{.016921}{\sqrt{v}}$$

e = is assumed at an average of .505.

ASSESSMENT.

The following are some of the plans adopted in assessing the cost of sewers:—

(*a*) Assessing the whole cost upon the corporation.

(*b*) Assessing the whole cost upon the property immediately benefited per foot frontage.

(*c*) Assessing the whole cost upon the property immediately benefited, per area of each property.

(*d*) Assessing the whole cost upon the property immediately benefited, per value of each property.

(*e*) Assessing the whole cost upon the corporation and charging for permits to make private connections.

(*f*) Assessing a portion of the cost upon the property immediately benefited, per foot frontage, area, or value of property, and the balance upon the corporation.

(*g*) Assessing the whole cost upon the property immediately benefited, per foot frontage, area, or value of property in proportion to its distance from the outlet of the sewer.

Theoretically, property should be assessed in proportion to its distance from outlet. For example, A lives 100 feet from the outlet; B 200; C 300; D 400; and they each wish drainage but cannot agree to combine but instead build four separate sewers; A 100 feet; B 200; C 300; D 400; or 1,000 feet in all. The question then arises if they had combined and built 400 feet for their common use, should A's portion be 40 feet; B's 80; C's 120; D's 160; or should their portions be equal? Another item to be taken into consideration is that A could drain alone by a small pipe, but if B, C, and D drain into his, the size of A's pipe will have to be increased.

There is a case of assessment in Owen Sound on three brick sewers, in which the assessment increases as they approach their outlet inversely to the above theory.

The assessment on Division Street sewer in the said town is 21.75 cents per foot frontage on the block nearest its outlet; 18.68 cents on the second block; 11.83 cents on the third block; and 8.84 cents on the fourth block; the whole street having the same sized sewer. There are two other main sewers assessed in the same way. How the property owners stood it is a mystery.

The basis of assessment which has been adopted by the writer, and which, in his opinion, is the proper and most equable one, is as follows:—

Assess the cost of the smallest sewer in the system upon the property benefited per foot frontage; assess the cost of all street intersections and the difference between the cost of a larger sewer and the cost of the smallest sewer upon the corporation.

For example.—Mill Street sewer in Chesley is an 18″ pipe, and Mary Street is an 8″ pipe, the smallest in the system.

According to the above basis of assessment the property owners on Mary Street should pay the whole cost of their sewer less street intersections, per foot frontage; the property owners on Mill Street should pay the whole cost of an 8″ sewer on their street less street intersections, per foot frontage; and the corporation should pay for all street intersections and the difference of cost between an 8″ sewer and an 18″ sewer on Mill Street.

CONSTRUCTION OF SEWERS.

Assuming that the plans of the sewerage system have been accepted by the Provincial Board of Health and by the village council; and that the proper steps have been taken in regard to initiating local improvements; the next step is the construction of such sewers or sewer.

The engineer should prepare a plan or plans of the sewer to be constructed on a large scale shewing the plan and profile, the depths at every 100 feet, the quantity and size of the pipe required, the quantity and size of the "T" or "Y" junctions, and the number of the man-holes or lamp-holes; besides detailed drawings of man-holes, catch-basins, or lamp-holes; and also specifications of the work. Tenders should then be advertised for in approved manner.

SPECIFICATIONS AND GENERAL CONDITIONS.

DRAWINGS.—All works are to be executed according to the drawings and plans exhibited at the town engineer's office at the time of the taking of tenders, or such others as may be furnished by him from time to time during the progress of the said work.

SYNOPSIS OF WORK.—The work shall include the excavating, refilling, laying of pipes and connections, building of manholes, street gullies, and flush tanks for a sewer on ——— street, from ——— street to ——— street. The contractor shall find all material, timber, tools, and labor necessary to carry on and complete the work. The contractor shall commence and carry on the work at any point along the line of the sewer the engineer may direct. No allowance will be made for any extra cost of a divergence from the line shewn on the plan to effect the proper connection at the outlet.

ALIGNMENT AND LEVELS.—Alignment and levels of the sewer will be given by the engineer, and the contractor shall be required to construct the sewer true to the alignment and grade. No claim for extra depth of excavation shall be considered unless such extra depth exceeds one-fifth of a foot on an average along the whole line of the sewer, and shall be paid for at the rate of one cent per lineal foot of one-tenth foot in depth.

WIDTH OF TRENCH.—The trench for the pipes shall be opened to a sufficient width at the top according to the nature of the soil to ensure a width at the bottom of at least one foot wider than the outside diameter of the pipe.

PROTECTION OF WORK.—The contractor shall, at his own expense, shore up, sling, protect, alter, divert, restore, and make good as may be necessary all water pipes, gas pipes, conduits, culverts, drains, sidewalks, crossings, pavements, or any other property which may be disturbed or injured during the progress of the work. He shall also keep a sufficient fence, lights—and a watchman if ordered by the engineer—on the works at night, in order to prevent accidents, and whether so ordered or not shall indemnify the corporation against all damages or accidents either to life or property which may in any way occur from his neglect.

PUMPING.—The contractor shall at his own expense pump out or otherwise remove any water necessary to be removed for the proper construction of the work, and shall make all drains necessary to keep the excavation clear of water during the progress of the work.

ROAD METAL TO BE PRESERVED.—The road metal on the surface shall be carefully placed on one side of the trench, and not allowed to be mixed with the earth excavated afterwards; when the earth has been properly refilled the good road metal shall be replaced and well rammed down.

MATERIAL ON STREET.—The contractor shall place all material and the earth from the excavation so as to interfere as little as possible with street traffic.

REFILLING.—The excavated earth shall be carefully refilled and well rammed, with rammers provided by the contractor, in layers one foot in depth throughout the whole fill. No stones larger than a twelve inch cube shall be allowed in the refill.

JOINTING THE PIPES.—In quicksand bottom the pipes shall be laid to the proper grade on a foundation of plank, concrete, or gravel, according to the order of the engineer and when so ordered shall be paid for at a price previously fixed. The pipes shall be laid on an even grade, the sockets being free from any extra pressure, and each pipe shall have an even bearing throughout its whole length.

JOINTING THE PIPES.—The jointing of the pipes shall be concentric and formed first of a gasket of oakum forced tightly between the socket of the one pipe and the spigot of the other by a proper caulking tool, and then the space between the socket and spigot shall be filled with cement mortar well forced in, the joint shall be then protected by a ring of soft blue clay or cement mortar moulded around it. Before making a joint all water shall be removed from the trench. The cement mortar shall consist of one part best Portland cement, and one part of clean sharp sand well mixed with clear water; care shall be taken to prevent any lumps of mortar from dropping into the interior of the pipe. A bundle of hay or straw shall be kept in the upper end of the pipe previously laid and pulled along with a rope as each successive pipe is laid to prevent any earth, gravel or sand from entering the pipe.

CLEARANCE OF STREET.—On completion of the work, the street shall be cleared of all rubbish, stones, earth, gravel, sand, tools or lumber, and shall be left in as good a condition as when the work was entered upon. All surplus stones, earth, gravel or sand shall remain the property of the corporation, and shall be delivered on the order of the engineer to any point within one-half mile of the work.

CONDUCT OF WORK.—The contractor shall suspend work if the engineer deem it necessary from any condition of the weather, soil or other causes, and shall not be entitled to any claim, for any compensation on account of such suspension.

CONNECTIONS.—All connecting pipes as shewn on the plan shall be placed as directed by the engineer and shall be included in the tender for sewer.

JUNCTIONS TO BE MARKED.—The location of each "Y" junction shall be marked by a two-inch square cedar stake two feet in length driven opposite to it at the street line.

DEAD EYES.—All "Y" junctions and the upper ends of pipes shall be closed with a wooden dead eye, which shall be well plastered on the outside with soft blue clay.

FLUSHING.—At its completion the sewer shall be well flushed free from end to end of all sand, earth, or gravel. The contractor shall flush during the progress of the work if the engineer deem it necessary.

QUALITY OF PIPES.—The pipes shall be salt-glazed vitrified clay, perfectly burned and thoroughly glazed over their entire inner and outer surfaces, shall be truly circular in bore, socket and spigot, perfectly sound and entirely free from blisters, cracks or defects, either two or three feet in length with socket joints. The inner surface of the socket and the outer surface of the spigot shall be well corrugated.

CONCRETE.—The concrete shall be composed of one part of the best Portland Cement, three parts of sand and five parts of broken stone, or clean washed gravel, to be well mixed, and thoroughly rammed down in place, no stones greater than a two inch will be allowed to be used.

Cement.—The contractor shall place a sample of the cement he intends to use in the hands of the engineer at least seven days previously to commencing work in order to test the same and any brand of cement not up to standard will be rejected.

Cement Mortar.—The cement mortar for the joints of the pipes shall be composed of one part best Portland Cement and one part of clean, sharp sand, that for manholes, flush-tanks and street gullies of one part best Portland Cement and three parts of clean, sharp sand. Both mortars shall be well mixed with clean water.

Bricks.—All bricks to be used shall be of the best quality, sound, and hard burned, of uniform size and shape; before being laid they shall be immersed in water. Each brick shall have full mortar joints on bottoms and sides and ends.

Manholes, Flush-tanks, Street Gullies.—Manholes, flush-tanks, street gullies and lamp holes, as shewn on plan, shall be built as directed by the engineer, and shall be included in the price of the contract. The manholes shall be circular of a nine-inch brick wall on a foundation of six inches of concrete, built with cement mortar, and shall be surmounted by an approved cast iron cap weighing at least four hundred pounds. Steps made of round wrought iron three-quarters of an inch in diameter of approved pattern shall be built into the walls of the manhole eighteen inches apart vertically.

Sewer May be Used.—The Board of Works reserves the right to connect any other sewers or drains with the contract sewer previously to the date of taking the work off the contractor's hands.

GENERAL CONDITIONS.

Order of Engineer.—The contractor shall obtain a written order from the engineer before proceeding with any work which may be charged as an extra, and absolutely no claim for such will be considered unless such order is produced, and on which there is a price stated. All contract prices shall be absolutely fixed as described in the blank form of tender and no extras will be allowed for quicksand, hard pan, rock or other material not specially mentioned.

Specifications and Plans.—Should any discrepancies appear, or should any misunderstandings arise as to the meaning and import

of the specifications or drawings, or as to the quality or dimensions of the material, or the due and proper execution of the work, or as to measurement, quality and valuation of the work, or as to the extras thereon, or deductions therefrom the same shall be explained by the engineer and this explanation shall be final and binding upon the contractor, and the contractor shall execute the work according to such explanation without charge or deduction as the engineer shall assess.

Setting Out and Keeping Correct.—The contractor shall set out and keep correct the work in every particular according to the plans and specifications, and shall be held responsible for the correctness of the proper line and grade of the pipe after it is covered in throughout the whole term of his contract.

Term Engineer.—The term engineer shall apply to the town or village engineer for the time being or some other officer appointed by him or the council to act for him, and he shall be the sole judge of the quantity or quality of the work done, and his decision shall be final as against the contractor, and should the work be not progressing to his satisfaction he shall have full power to take the contract or any part of it out of the hands of the contractor and to relet the same, or otherwise complete it, first having reported the same to the Board of Works, and having obtained the sanction of the council thereto and thereupon, all moneys due or falling to the contract, or shall be forfeited and shall be applied to the completion of the contract. Any balance after completion shall be returned to the contractor.

Contractor's Agent.—In the absence of the contractor from the work, his foreman or other person in charge shall be considered as acting in his place, and all orders to such agent by the engineer shall be as binding on the contractor as though given to himself in person.

Employees.—The employees of the contractor shall at all times obey the direction of the engineer, or his deputies, with respect to the work, and if any foreman, agent or employee of the contractor shall be found incompetent or has created disturbance on the work shall, on the order of the engineer, be discharged.

Date of Completion.—The contractor shall complete the whole of the work on or before the ..... day of ..... A.D. 190.., or shall pay ten dollars per day—subject to the decision of the council—as liquidated damages for each and every day that any part of the contract shall remain unfinished after that date.

Failure to Complete.—If the work be not completed on or before the ..... day of .....A.D. 190.., the council shall take the unfinished work out of the contractor's hands.

Payment.—Upon acceptance of the work by the Board of Works, on the certificate of the engineer that it has been completed to his satisfaction, the contractor shall be paid ninety per cent. of his contract price, the balance, ten per cent., shall be paid the.....day of ..... A.D., up to which time the contractor shall be bound to uphold the work in every way.

Completion to be Satisfactory.—The whole work shall be completed in a workmanlike manner, and to the true meaning and intent of the specification, and to the satisfaction of the engineer and Board of Works.

Tenders.—Tenders shall be made according to printed form. Each tender shall be accompanied by a certified bank cheque for the sum of five per cent. of the tender, payable to the order of the village treasurer, which sum shall be forfeited if the party decline the contract or fail in the performance thereof, but will be returned in case of non-acceptance.

C....., May....., 190...

Village Engineer.

TENDER.

Form of Tender.—I, ..., contractor of the town of ..... Ontario, hereby tender for the construction of an 8″ pipe sewer on ..... Street in the V..... of ....., at the following schedule of prices, and enclose a certified bank cheque made payable to the treasurer V..... of ..... for the amount of $....., being 5% of my tender.

SCHEDULE.

..... manholes	at $.....	$.....
..... lampholes	at $.....	$.....
..... catch basins	at $.....	$.....
..... feet of 8″ pipe	at $.....	$.....
..... feet of 9″ pipe	at $.....	$.....
..... feet of 12″ pipe	at $.....	$.....
..... feet of 15″ pipe	at $.....	$.....
..... feet of 18″ pipe	at $.....	$.....
..... feet of 6″ pipe	at $.....	$.....
..... feet of 6″-8″ Y jcts.	at $.....	$.....
..... feet of 6″-9″ Y jcts.	at $.....	$.....
..... feet of 6″-12″ Y jcts.	at $.....	$.....
..... feet of 6″-15″ Y jcts.	at $.....	$.....
..... feet of 6″-18″ Y jcts.	at $.....	$.....
..... feet of 8″-8″ T jcts.	at $.....	$.....
Total		$

..... May 21st, 190... .....

Contractor.

SHORT FORM OF AGREEMENT.

THIS AGREEMENT, made and entered into this day of..... A.D. 190.....

BETWEEN..... of the ..... in the County of....., contractor of the First Part.

.. and

The Corporation of the ..... of the Second Part.

WITNESSETH: that the party (or parties) of the First Part do hereby for themselves and each of them, their heirs, executors, administrators and assigns, covenant, promise, and agree with the parties of the Second Part in the manner following, that is to say:

CONSTRUCTION.—That, they the parties of the First Part, shall or will for the consideration hereinafter mentioned, on or before the ..... day of ..... 190 , well and sufficiently execute and perform in a true, perfect and thoroughly workmanlike manner, all the work, and supply all the materials, labor, tools, machinery, apparatus and cartage of every description required in the excavation for and the completion of a pipe sewer commencing at ..... street, thence along ..... street to ..... street, &c., in the ..... according to the plans, drawings, specifications, and general conditions prepared for the said work by ....., ... Engineer, and signed by the parties of the First Part, and the said ....., which plans, drawings, specifications and general conditions shall be deemed to be incorporated in and to form part of this contract; the said work to be done and the said sewer to be constructed under the direction and personal supervision of the said .... Engineer, or such person as the said parties of the Second Part may appoint as his successor as Engineer in charge of the said works. The said sewer to be built and the said work to be complete and finished according to the said plans and specifications on or before the ..... day of ..... 190....

CONSTRUCTION.—The said parties of the Second Part do hereby covenant, promise and agree to and with the said parties of the First Part, their heirs, executors, administrators and assigns, that they the said parties of the Second Part shall and will in consideration of the covenants and agreements being strictly executed, kept and performed by the said parties of the First Part, or unto their heirs, executors, administrators or assigns, upon the certificate of the said .... Engineer or his successor, or as aforesaid, pay the sum of ..... dollars; the said sum to be paid as follows:—Eighty-five per cent. of the said sum to be paid when the work is completed by the said parties of the First Part, in accordance with the plans, drawings, specifications and general conditions, and shall have been accepted and approved by and shall have passed the inspection of the said..... .... Engineer, or his successor as aforesaid, and fifteen per cent. at the expiration of one year from the date of such completion and acceptance and approval by the said Engineer, and of such passing of inspection.

In witness whereof the said parties have hereto set their hands and seals.

Signed, sealed and delivered in the presence of

.....

.....

.....

.....

.....

.....

Contractor.

Sureties.

Mayor.

Clerk.

Corporate Seal.

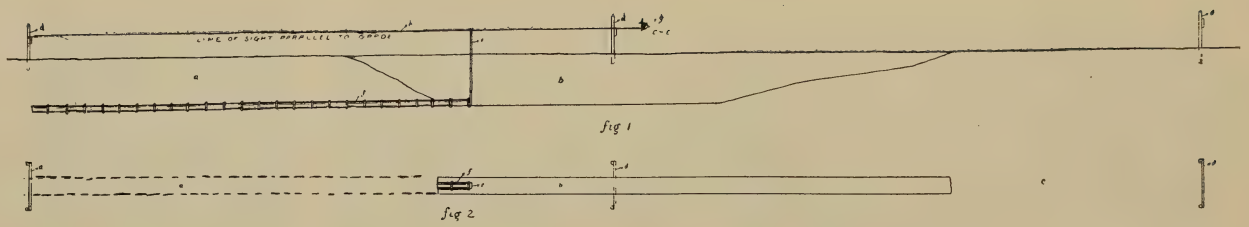
DETAILS OF CONSTRUCTION.

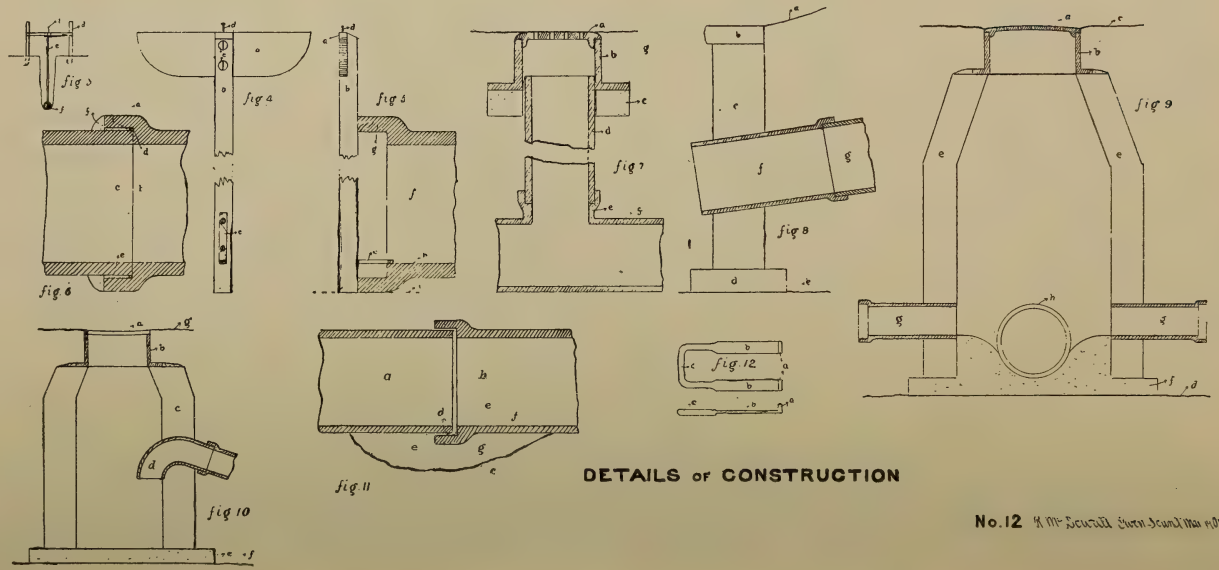
In general all sewers should be started in their construction at their outlet or lower end and continued up grade to their upper end. The reasons for this are as follows:—

(*a*) The spigot or small end of the pipe is always laid down grade and the bell, socket or larger end of the pipe up grade; it can easily be seen that in making a joint it is a great deal handier to insert the spigot into the socket than place the socket over the spigot; and also much easier to fill a joint facing outward, with cement, than one facing inward. The spigot end is placed down grade for the reason that, being inserted into the socket the sewage flows past the joint whereas if placed up grade the sewage would be apt to flow through the joint. (*b*) By constructing from outlet up grade any water that accumulates in the trench from springs or rainfall can flow through the sewer, but would have to be removed by bailing or pumping by constructing in the opposite direction.

If the outlet of a sewer is in a body of water a retaining wall should be built about the first pipe in order to support it, and also the river bank. Fig. 8, Plate No. 12 shews a vertical section of such a wall, "a" is the bank; "b" the cap; "c" the wall; "d" the foundation; "f" the first pipe; "g" the second pipe.

As in the excavation for a sewer any grades or alignment placed on the ground would be removed the engineer has to resort to a plan to secure them. This is done by placing cross-heads every hundred





DETAILS OF CONSTRUCTION

No. 12 H. M. Bucknell, Burn. Scan. Mag. 1901

feet to a grade parallel to and at a certain distance from the proper grade, and on top of the cross-heads, driving a nail on the alignment. The grade of the pipe is transferred from the parallel grade by means of a rod called a boling-rod the length of which corresponds to the distance between the proper grade. The alignment is obtained by dropping a plumb line from the nail in the cross-head.

The invert or lower inside part of the pipe is considered the grade of a sewer.

Figure 1, Plate No. 12 shews a longitudinal section of a sewer under construction; fig. 2 is a plan of the same; fig. 3 is a vertical cross-section of the same. In all figures "a" is the filled in trench; "b" the excavated trench; "c" the unexcavated trench; "d" the cross-heads; "e" the boling-rod; "f" the sewer pipe; "g" the eye of the engineer or inspector sighting over the cross-heads and boling-rods; "h" the parallel line of grade; "i" the nail in the cross-head.

A cross-head consists of two upright pieces of 4″ by 4″ scantling placed firmly in the ground, one on each side of the trench, about 10 feet apart, and at right angles to the line of the sewer; to which is nailed horizontally a piece of straight edged pine board 1″ by 6″.

A boling-rod consists of an upright piece of wood 1.25″ by 1.25″ and of sufficient length to reach from the line of the top of the cross-heads to the bottom of the trench, having a piece of 4″ by 12″ pine fixed to it at its upper end in the form of a "T"; and at its lower end a piece of wrought iron in the form of an "L", fixed so that the distance from the top of the rod to the bottom of the "L" equals the distance from the top of the cross-heads to the grade of the sewer. Figs. 4 and 5 shew front and side views of the boling-rod, in which "a" is the head piece; "b" the upright; "c" the "L" piece resting on the invert "h" of the pipe "f"; "e" screw nails; "d" nail for line of sight; and "g" the socket of the pipe "f." In order to find if the bottom of the trench is to grade, place the boling-rod upright, with its lower end resting on the bottom; sight across the cross-heads, and if the top of the rod is in line of sight the trench is at grade; if above the bottom of the trench is too high and *vice versa.* The grade of the pipe is found in the same way, with the exception that the "L" of the rod rests on the invert of the pipe and its lower end on the bottom of the trench.

The greatest care should be taken when laying pipe sewers to make a proper joint. Fig. 6 shews a pipe joint in section, in which

"a" is the socket end of the pipe "b"; "c" is the spigot end of another pipe; "d" the gasket placed around "c" to prevent the cement in the joint "e" from dropping into the pipe; "f" is a roll of soft blue clay or cement mortar placed around the joint to prevent water from forcing the cement, before it has had time to set, out of the joint "e."

Fig. 11, Plate 12, is a section of a pipe joint shewing the probable cause of collapse of a sewer in quick sand or other watery ground in which "a" is the spigot end of a pipe; "b" the socket end of another; "c" the sand below the pipe; "d" an open joint; "e" moving sand carried into the pipe through the open joint; "g" the cavity below the pipe. These pipes having been undermined will either crush, shear off, or be pressed out of grade by the pressure from above, but in such a case the collapse is assured.

Manholes are generally built at the intersection of the centre line of two cross streets, or at any change in the grade of a sewer. They are requisite as forming junctions for pipes leading in from other streets and catch-basins; as ventilators; for examination of sewers; for flushing, &c. They are generally built of hard brick, either square or circular in shape, from 3 to 4 feet in diameter. The bottoms of the manholes should be filled in with concrete, smooth and even, so as to form runways to prevent the sewage from being stranded. Fig. 9 Plate 12 shews a vertical cross-section of a manhole in which "a" is a cast iron cap; "b" a cast iron top; "c" the ground surface; "d" the bottom; "e" the walls; "f" the concrete foundation; "g" "g" two side sewer pipes; "h" the main sewer pipe. Fig. 12 Plate 12 shews the form of the iron steps built into the walls of the manhole in which "a" is a projection which catches on the back of the wall of the manhole; "b" the wrought iron flattened so as to be laid in the wall; "c" is the round iron used as the step.

Catch-basins or street gullies at the street gutter near the sidewalk curb, to catch the street water and lead it to the sewer. Fig. 10, Pate 12 shews a vertical cross-section of a catch-basin, in which "a" is a cast iron grate; "b" is a cast iron cap; "c" is the wall; "d" is a 6″ elbow built in the wall.

In conclusion the remark that "cleanliness is next to godliness" may be applied to a civic corporation. And in order to have civic cleanliness a sewerage system having a swift outlet, maximum grades, and good ventilation is an attribute.

THE TESTING OF RAILWAY MOTORS.

By P. H. Mitchell, '03.

Although this paper will deal mainly with the application of tests to railway motors, an idea can be had of the requirements of tests for direct current motors in general.

The electric railway motor is being continually changed in detail according to the service required of it. Many roads will require a perfectly new type of machine designed for its particular conditions. The rated capacity varies from about 15 h.p. to 200 h.p. There is a general form, however, which it will be well to consider.

The modern railway motor is an entirely closed structure. Experience shews that the motor should be protected from the dirt and moisture that is bound to accumulate in service. The frame or housing of cast iron or steel is approximately cylindrical in shape and of the smallest dimensions possible. It is usually divded into halves, so that it can be readily taken apart or inspected.

There are usually four pole pieces. These are made up of laminated, soft steel or iron punchings, riveted together and cast in the frame or attached to it by bolts. The latter way is more satisfactory as better spacing is secured. The coils of wire are form-wound and thoroughly protected by an insulating covering with good heat conducting qualities.

The armature core is also laminated, and must be comparatively small or its inertia will be a defect in starting or stopping suddenly. The core should be provided with air passages, which are adequate to carry off the heat generated in coils and core. Throughout all the construction the ventilation must be carefully considered. The armature coils are held in longitudinal slots by means of wedges or by binding wire which is wound about the armature. A small number of ampere-turns is advisable so as to have low self induction. If the self induction is high it offers a greater resistance to the reversal of the current, thus producing sparking.

As the machine must run in both directions the brushes must be set on the neutral point to obtain good commutation. Carbon brushes are used in radial brush-holders, which are attached to the frame. Two brushes are usually sufficient for the higher voltages where the current is not so great, but four brushes could be used without altering the characteristics of the machine. When the brushes have a backward lead the commutation is best for forward running, but when the machine is reversed the brushes will have a forward lead which is objectionable and necessitates the shifting of the brushes. When the brushes cannot be shifted for each reversal it is necessary to leave them on the neutral point.

The capacity of a railway motor is limited by the sparking at the commutator, and by the heating of the armature and field coils. The heating of the windings does not depend only on the current, but also upon the duration of the load. Upon this the rating is based. If a motor is rated at 50 h.p. it signifies that it should run for one hour with full load and have its rise of temperature within safe limits, 75° C rise from 25° C, being considered safe. This temperature is seldom produced as the load rarely reaches that point, and ventilation is better when in service.

Since a large starting torque is required to start a car on either a level or a grade the series wound motor is always used. As the armature current passes through the field windings, a series wound machine is capable of enormous starting torque because the torque is proportional directly to the product of the field strength, and the armature current, and the field strength and armature current will here increase together.

Every machine must undergo a commercial test. The methods employed for this are many, but they all have about the same requirements. In large shops, for many reasons, it is found cheaper to build two similar machines together—even if only one is ordered, the other is retained for stock. Where this is done the following method may be employed.

The motors are placed with their gear ends together (Fig. 1), and joined by some good flexible coupling which will not necessitate great care in lining up. The motors are clamped to a bed plate. When one machine runs as a motor the other can be run as a generator and electrically loaded, by this means we can regulate the current or load on the motor.

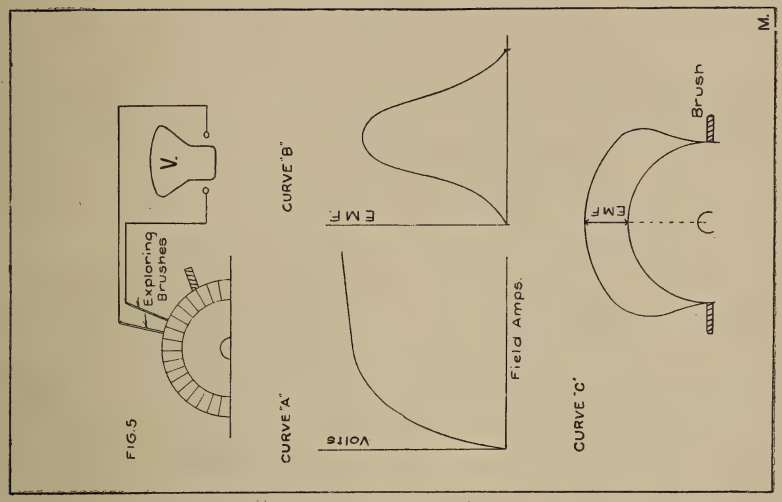


FIG.5
Exploring Brushes
V.
CURVE 'A'
Volts
Field Amps.
CURVE 'B'
E.M.F.
CURVE 'C'
E.M.F.
Brush
M.

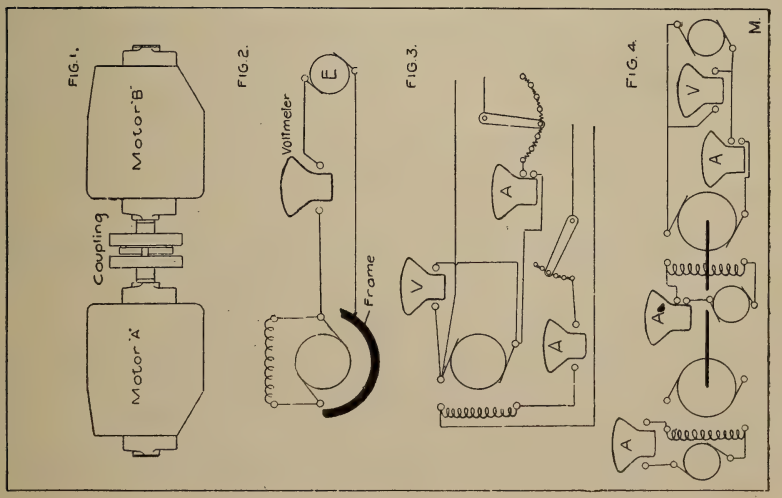


FIG.1.
Motor 'B'
Coupling
Motor 'A'
FIG.2.
Voltmeter
E
Frame
FIG.3.
V
A
A
A
FIG.4.
V
A
A
A
M.

I will give this test in detail. For convenience let us consider the test of two similar machines of about 50 h.p. and 500 volts. Call them "A." and "B." respectively.

The first requirement is a test for grounds in each machine. It should be perfectly safe in this respect with the application of a much higher voltage than that for which it is rated. A 500 volt machine should stand 3,000 volts A. C., between the frame and the windings. This test should discover the presence of any weak spots. The high voltage is locally obtained from a portable step-up transformer from 110 volts A. C. for the primary pressure. A circuit breaker should be in the secondary circuit. Several steps of windings on the secondary which can be easily manipulated make it a source of any voltage we need in this kind of testing. One terminal of the transformer is applied to the windings, the other to the iron or steel frame. If there is a circuit caused by a ground, the circuit breaker, being set for very low current, will fly open. The ground can be located by re-applying the current and watching for the flash or burning insulation, &c., inside the motor. Sometimes, however, the ground may not be visible. The machine must then be taken apart and the ground searched for.

A very necessary preliminary test is to determine if the insulation resistance is sufficient. Measurements should be taken both hot and cold. The resistance will be found very much lower hot than cold, especially when the machine is rapidly heated. About 1 megohm is considered sufficient resistance. This is conveniently measured by means of a high resistance voltmeter and direct current. The voltmeter should be read when connected in series with the unknown resistance across the D. C. lines (Fig. 2). If "e" be the observed voltage, "V." the voltage of the line and "R." the resistance of the voltmeter, then the insulation resistance is $R\frac{V-e}{e}$. With a 500 volt voltmeter reading across 500 volts D. C., one megohm or 1,000,000 ohms in series with the voltmeter gives a deflection of about 35 volts (assuming resistance of voltmeter equal to 75,000 ohms).

In the running test we need a source of current of 500 volts. This pressure is not always obtainable so we must have a "booster" in the circuit. A booster is a generator run by a motor or some other steady power. The line with the pressure which we wish to raise or lower has the armature of the booster generator in series with it.

The field is separately excited by, say, 110 volts, and is completely controllable by a rheostat. By generating an E. M. F. in the same direction as the line E. M. F. we can "boost up" or by an opposing E. M. F. "boost down" the voltage, and thus obtain exactly what we wish.

We also require resistance for the load on the generator or motor running as a generator. This is handily arranged with heavy low resistance coils which can be readily placed in series or in parallel across the generator terminals. The less the resistance of course, the greater the current and the greater the load on the generator and motor. A rheostat for heavy currents in series with the rack of resistance will give a fine adjustment of the load.

As there is not likely to be any residual magnetism in the poles of a new motor it will be necessary to send a current through the field of the machine, say B., which first runs as generator. This will magnetize the field and on withdrawal leave some residual magnetism and allow B. to readily "pick up" its load. At the same time we can test for the electric circuit and get the cold resistance. Current is sent through both machines in such a way that they will "buck" or oppose the rotation of each other. We can thus put a heavy current through without motion and get resistance of both field and armature undisturbed by C. E. M. F. in the armatures. This is done by placing a voltmeter across each part and taking the drop. If we had 50 amperes flowing through each machine and the voltmeter read 20 volts across a field, we would get R. in ohms from $R = \frac{E}{C}$ derived from Ohm's law; here $R = \frac{20}{50} = .4$ ohms.

Now we are ready to start the motors on a temperature run. As in practice a railway motor seldom is fully loaded, a $\frac{3}{4}$ load is a high test, this load being given for 1 hour. The temperature limit, of course, is reduced for this (about 45°C rise is allowed). An overload of $1\frac{1}{4}$ load is also given for a few minutes.

Suppose the $\frac{3}{4}$ load is 68 amperes. $1\frac{1}{4}$ load for this particular machine would be say, 118 amperes. Experience teaches the amount of resistance required for this load of 68 amperes, and enough load should first be put on the generator B to keep the motor A from "running away." The load is brought up to 68 amperes by arranging the resistance in the rack; the voltage is 500, and the standard speed

is say, 600 R.P.M. A variation of 5% in speed is allowed, that is, it may fall to 570 or go as high as 630, and be considered all right in this respect. The speed of a series motor will drop when the machine becomes heated. The number of revolutions is taken by means of a speed indicator and watch, or by a tachometer, and noted on the test-sheet which will contain the record for the whole test. The direction of rotation is also noted, whether right handed or left handed, i.e., clockwise or counterclockwise respectively.

The machine B, which has been running as a generator, will now take its turn as a motor, and the same tests repeated. This machine now runs for half an hour as a motor, and then again the speed is taken on a $\frac{3}{4}$ load. The drop across the field is measured again. The resistance is worked out from this and by its rise we can keep track of the rise in temperature, allowing $2\frac{1}{2}$°C rise for 1% rise in resistance of the copper wire.

The current through the armature of B is now reversed, and the machine rotates in the opposite way. The current is made the same in amount as before and the speed taken. The speed in one direction should check with the speed in the other, shewing the symmetrical arrangement of the brushes. If the speeds are not nearly the same the brushes must be shifted—a backward lead in one direction being a forward lead in the other, causing higher speed in the former than in the latter direction.

A $1\frac{1}{4}$ load is now applied. The speed will drop considerably, say to 475 R.P.M. from 600. A is then run again as a motor, and the $1\frac{1}{4}$ load applied on it, then the $\frac{3}{4}$ load in each direction and resistance of the field taken. A runs for half an hour with the last load and the speed taken again. This gives us the speed when the machine is in a fully heated condition. B is again run for this speed, and the resistance of the field taken.

By watching the rise in the field resistance we can well keep track of the temperature rise. This is often supplemented by taking temperatures with thermometers, although here we merely get the surface conditions. If the temperature of the outside of the insulated field coil is about the same as the coil itself by the resistance method, we conclude that the insulation is a good conductor of heat. The following method of taking temperatures by thermometers is employed:—The ordinary thermometers such as we have in the laboratory are used. Temperature of field coils should be taken by thermometers laid on the

surface, and covered with waste. The same way with the armature, care must be taken, of course, that the armature is not turned so as to break the thermometer. The commutator must receive the first attention, as it cools very fast. The temperature is read every few minutes until a maximum is reached, this is rated on the test sheet.

This completes a one-hour heat run for each machine, and after final insulation tests and a high speed run the entire commercial test is completed.

The machines are now separated from each other and the current slowly turned on and each motor allowed to speed up on no load. A machine of this kind should safely run at 1,800 R.P.M., or about 3 times its rated speed. This speed must be determined by a tachometer, or some device which will immediately indicate the number of revolutions per minute.

Leakage is again taken, and will be found to have very much increased, as the resistance of the insulation will decrease when heated. When the machine has cooled down enough, we can give it its final high voltage test. This is applied in the same way as previously stated, and if the machine stands it the motor is O.K.'d and leaves the tester's hands.

Of course, all these operations are controlled from one switchboard, on which the simplest and handiest arrangement of switches, plugs, &c., possible, is used.

I will now give the methods of applying such tests as for hysteresis, eddy currents, and friction of the armature, the tests required for saturation curves, field distribution and the determination of the commercial efficiency.

The losses in a motor armature can be divided into three groups, thus:—

I. Copper losses—
   (*a*) Armature C^2R loss.
   (*b*) Loss by eddy currents in wire;
II. Iron losses—
   (*a*) Hysteresis,
   (*b*) Eddy currents;
III. Friction losses,
   (*a*) bearing,
   (*b*) brush,
   (*c*) air resistance;

With the exception of the air resistance loss, all evidence themselves as heat.

The resistance and friction losses usually occasion the greatest rise in temperature; in a well designed machine the rise in temperature due to the iron losses can scarcely be noticed.

Hysteresis can be partly overcome by careful selection of the iron. Very thin, soft, sheet iron gives best results. Steimnetz gives the following formula for hysteresis loss in ergs per cubic centimeter of iron, per cycle $H = nB^{1.6}$, where n is a constant depending upon the kind of iron; thus n=.0015 for thin, soft, sheet iron, and=.025 for hardened cast steel. Now from this we see that the hysteresis loss varies directly with the speed, and with the 1.6th power of B, the density of lines through the revolving armature iron.

Eddy currents are local currents in the iron core, caused by the E.M.F.'s generated by moving the core in the field. The loss increases as the square of the number of revolutions per second and as the square of B. This loss is considerably decreased by insulating between the core disks by varnishing or rusting the disks, or by applying paper insulation. To provide better ventilation the core usually has ventilating ducts.

Friction is found to be practically constant for all loads at constant speed, and varies directly with the speed.

The armature C^2R loss is easily calculated, and the loss by eddy currents in conductors is made negligible by using several small conductors in parallel instead of one large one. We can determine the total losses of eddy currents, hysteresis, and friction by this method.

The motor is run separately excited with a constant field and no load. Current is supplied to the armature and varied to give a range of speeds. (Fig. 3).

VC_a = Power delivered to armature;

$C_a^2R_a$ = Power wasted in heat in armature winding;

$VC_a - C_a^2R_a$ = Stray power;

Now $E = V - C_aR_a$

$EC_a = VC_a - C_a^2R_a$ = Stray power.

The last equation gives the losses in watts in terms of the two readable quantities, "V" the drop across brushes; and C_a the current through the armature.

To further separate, since eddy currents vary as the square of the speed, and hysteresis and friction vary directly with the speed, we can determine the eddy currents thus:—

L=total loss in watts;
F=loss in friction;
H=loss in hysteresis;
D=loss in eddy currents;
$L=F+H+D$ at first speed, (1)
$KL=L_1=KF+KH+K^2D$ at some other speed (2)
K times the first, where $K=\frac{1}{2}$ say,
$K \times (1) = KF + kH + KD$, (3)
(2)-(3)=K^2D-KD,
$L_1-KL=KD\ (K-1)$,

$$D=\frac{L_1-KL}{K\ (K-1)}$$

Now as hysteresis and friction vary directly as the speed we must obtain one of these losses to get the other. The friction value can be approximately determined in watts. The machine is run as a series motor on a very low voltage, and the loss $VC - C^2R$ is plotted as before on a speed base. This neglects the slight core losses which are present, as the field is very weak.

Having found the total losses, and subtracted eddy currents and friction losses, the hysteresis loss is the remainder.

When a dynamo or motor is to be run at a rated speed the core loss is usually obtained for that speed under varying conditions of field. Curves are plotted on a basis of watts loss for field amperes.

This is obtained in the following manner. (See Fig. 4).

The armature under test is belted to a motor through which is electrically measured the work done in the system. The instruments required are:—a voltmeter across the motor aramature, an ammeter in the motor circuit, and one in each field. A rheostat should be placed to control the field of each machine. A speed indicator is required to determine the speed.

If friction is required in watts we must connect motor and dynamo shaft by some flexible coupling, as in using belting we will introduce complications. The power required to drive the motor alone at the rated speed is equal to the product of the impressed voltage and the current through the armature; of this C^2R is copper loss.

The motor is then connected up to the armature, and the power consumed in revolving it at the standard speed with absolutely no field is determined.

V = impressed voltage at motor;

C = current through armature running light;

C_a = current through motor armature when connected to dynamo armature;

R = resistance of motor armature.

Then $(VC_a - C_a^2R) - (VC - C^2R)$ = friction loss in watts at standard speed.

Now supply a series of field currents to the field of the machine under test, and note the power consumed by the motor while still attaining the standard speed.

As the dynamo's field increases so do the stray power losses in the core, and the motor must be supplied with more current or the speed will fall. These increases in the amount of current represent the rise in the hysteresis and eddy current losses since the friction is constant with constant speed. In each case we must subtract the C^2R from the motor's input.

If we wish to separate the brush friction we can do so by taking the friction test with brushes off and brushes on. The difference gives this loss in watts.

The commercial efficiency of a dynamo or motor is equal to the net input divided by the output.

or $f = W_o \div W_i = W_i - L = W_o \div (W_o + L)$.

Where f = commercial efficiency;

W_o = output in watts;

W_i = input in watts;

L = total loss.

In the case of a generator, where the output can be measured electrically,, we should use the last form; in the case of motors we should use the second expression. L, the total loss consists of the armature losses previously mentioned, and the C^2R loss in the field. C^2R can be determined for any load provided we know the resistance warm.

The output of a motor is often determined by means of a Prony brake or dynamometer. In this test a pulley of suitable dimensions and construction is put on the motor shaft. To absorb the power a friction brake, consisting of a series of wooden shoes fastened at equal intervals

to a flexible strap of either leather or steel, encircles the pulley. The friction is adjustable by means of screws which put tension on the belt. An arm attached to the brake rests on the platform of a weighing scale and prevents the brake turning with the pulley.

Since heat is generated by the friction, some means must be taken for keeping the pulley cool. A common method is to provide the pulley with deep inside flanges, and after the machine reaches its proper speed water is poured in, which will, by the centrifugal force, stay in the inner circumference. By a suitable arrangement of pipes a flow of water to and from the pulley may be maintained.

The work done on the brake per minute is the product of the following terms:— l=the horizontal distance between the centre of the brake pulley and the point of bearing on the scales, in feet; n= number of revolutions of the pulley per second; W= force in pounds which brake exerts on scales less the tear or force exerted by the "dead" brake.

Power $= 2 \pi l$ n w=foot-pounds per second.

and H.P. $= \dfrac{2 \pi l \text{ n w}}{550}$

The input to the motor is measured in watts, and can be reduced to horse-power by dividing the watts by 746; or the power absorbed by the brake can be reduced to watts as follows: —

If the length l, be given in centimeters, and the weight, w, be taken in grains, the power absorbed by the brake is measured directly in ergs per second, and as one watt $= 10^7$ ergs per second, the watts output at the brake $= \dfrac{2 \pi l \text{ n w} \times 981}{10^7} = \text{Wo}.$

The watts input $= W_i$ and efficiency $\% = \dfrac{W_o}{W_i} \times 100.$

If the output is measured in l = feet and W = lbs., then $W_o = 2.72 \pi l$ w.

Input in h.p. $= \dfrac{W_i}{746} =$ h.p.

Output H.P. $= \dfrac{2 \pi l \text{ n w}}{550}$

And efficiency $\% = 100 \dfrac{\text{H.P.}}{\text{h.p.}}$

The next test to be considered is the saturation test. This shews the quality of the magnetic circuit of a dynamo or motor, and especially the amount of current necessary to magnetize the field cores and yokes to a proper intensity. The test is run with all the more

common sources of error, connections, loose joints, &c., eliminated. The armature must be driven by some outside power at a constant speed and without load. A voltmeter is placed across the brushes. The field must be separately excited and must have in its circuit a rheostat capable of fine adjustment of the exciting current, and an ammeter. We record the current in the field and the volts at the brushes, plotting a curve with the amperes as abscissae and the volts as ordinates. Should there be sufficient residual magnetism in the iron to produce any pressure without supplying exciting current, such pressure should be recorded; or perhaps a better way is to start at zero voltage by entirely demagnetizing the fields by momentary reversal of the exciting current.

To start the test, read the pressure, due to the residual magnetism if not demagnetized, or if demagnetized, start at zero. Give the fields a small exciting current, and read the voltage at the armature terminals; at the same time, read the current in the field, and the revolutions of the armature. Increase the excitation in small steps until the figures shew that the "knee" of the iron curve has been passed by several points; then reverse the operation, decreasing the excitation by like amounts of current, until zero potential is reached.

The rapid increase of E.M.F. at first shews the iron to be far from saturation, but as the "knee" of the curve is reached, the iron becomes more highly magnetized, and just past the "knee" is said to be practically saturated. Beyond this point increase in magnetization requires greatly increased exciting current, and it is uneconomical to use a larger current than that corresponding to the point just beyond the knee.

Closely related to this test is that of field distribution. We find the variation of the strength of field from point to point between the brushes, and decide whether we could make any improvement by altering any of the details of construction.

The method generally used in the determination of the field form, was devised by Silvanus P. Thompson, and consists in attaching the terminals of a sensitive voltmeter to two exploring brushes held far enough apart to span the insulation between adjacent bars of the commutator. (Fig. 5.) By moving these brushes from bar to bar of the commutator we can measure the voltage generated by each individual coil as it moves through that portion of the field while running at the rated speed. By plotting the voltage vertically, and the distance between the exploring brushes and the neutral point horizontally, we obtain a curve which shews us the distribution of the field. This

should be taken for no load and full load in the same manner. (Curve B).

Another way of plotting the readings is by representing the armature by a circle, and drawing the E. M. F. curve around it; considering the circumference of the circle as a base line and the vertical scale radial to it. (Curve C).

It will be noticed that in some machines we may explore several points from the neutral without any deflection of the voltmeter, and then it gradually attains the maximum, which with no load should be equidistant from each neutral point, and make the curve symmetrical. To facilitate this method, where many similar machines are tested, a strap or band of fibre-board, or other stiff insulating material of suitable dimensions to reach from brush to brush, is pierced with small holes evenly spaced to correspond with the spacing of the commutator bars in the arc to be explored. Hard lead pencils may be used as the exploring brushes by making good contact to the lead with the voltmeter terminals. The pencil points are put in adjacent holes and the voltage between them read. By numbering the holes we avoid the bother of measuring the distance traversed every time. The sum of these separate E. M. F.'s equals the voltage across the main brushes, if there is no CR drop at the contact points.

A regulation test consists in establishing the ratio between the drop in the speed of the motor from no load to full load, and the speed at full load. This ratio is called the regulation of the motor.

The full rated load is applied, and the brush and field rheostat (if any) are adjusted to meet the specified conditions of full load. Measurements at this point are taken and at about ten other points, as the load is gradually decreased.

At each step the following readings are taken:—

Amperes, input;

Volts at machine terminals (constant);

Speed of armature;

Amperes in the shunt field (if any).

As a large series motor cannot take rated voltage with no load, on account of the high speed developed, this is not applicable to this motor.

It is understood, of course, that in the process of construction of all machines, tests for grounds and all common faults of workmanship must constantly be applied while the machine is being assembled.

THE WATER SUPPLY OF BERLIN.

HERBERT J. BOWMAN, M. CAN. SOC. C. E.

In the year 1883, when the Town of Berlin had reached a population of about 4,000, the need of a public water supply began to be felt, more particularly to provide adequate fire protection, although the well water, especially in the business part of the town, was often contaminated. In the summer of 1884 the Town Council engaged Savage & Palmer, of Petrolea, who started to drive a 6-in. well at the corner of King and Foundry Streets, near the centre of the town. The well was put down a depth of 550 feet, but never flowed at the surface. A supply of strong mineral water was struck, sufficient to keep the steam pump procured for the purpose going at its full capacity. Afterwards it was proposed to pump this water for fire protection for the centre of the town, but finally a hand pump was put in, and for a year or two the man who sprinkled the streets made use of it to fill his cart. When the Economical Fire Insurance block was built the well was covered up, and there is now nothing to show for the $1,500 expended on this experiment.

In 1885 two different manufacturing concerns communicated with the Town Council in regard to a supply of water. The first communication was a request for assistance to put down another driven well not very far from the site of the first attempt and at about the same level. The opposition scheme suggested a supply of water from the Grand river, but no action was taken on either.

In 1886 the town, having grown to have a population of 6,000, the Council took up the water supply question in earnest, and sent a deputation to visit surrounding towns having water works systems. On the return of this deputation the Council prepared estimates for a proposed system of water works to cost $35,000. The source of supply was to be an artesian well, which it was confidently expected would be obtained if the experiment was tried at the low ground now covered by the artificial lake in Victoria Park, the elevation of which is about the same as the part of the adjoining town of Waterloo where artesian wells were quite numerous. So a by-law to raise the amount considered necessary was submitted to the ratepayers at the January elections in 1887. At that time this was considered a large sum to raise, and as there was no certainty of getting a supply of water, the ratepayers voted down the proposition. About ten years after, when Victoria Park was acquired, the Park Board put down a well near the site of the proposed pumping station, but only succeeded

Flow from an Artesian Well.

in getting a small flow of mineral water which afterwards ceased, so that the hesitation of the ratepayers to endorse this scheme was justified.

A few months after the refusal of the ratepayers to build a water works system at the public expense, the Town Council advertised that they would entertain offers from private companies, and in July, 1887, entered into a contract with Moffet, Hodgkins & Clarke, of Watertown, N.Y., to put down six and a half miles of water mains with 65 hydrants, at an annual rental of $3,190, and $45 each for any additional hydrants placed on extensions not more than 500 feet apart. The contract contained the following clause:—

"The water supply in the discretion of the company may be taken from the lake, known as Shoemaker's Lake, or from wells, springs, or other sources; provided, however, that the water supplied shall in the outset, and at all times thereafter, be ample in quantity for all the purposes aforesaid, and be pure, good and wholesome water, and shall at all times be subject to, and shall be such as shall be approved of by the Board of Health of the Town of Berlin."

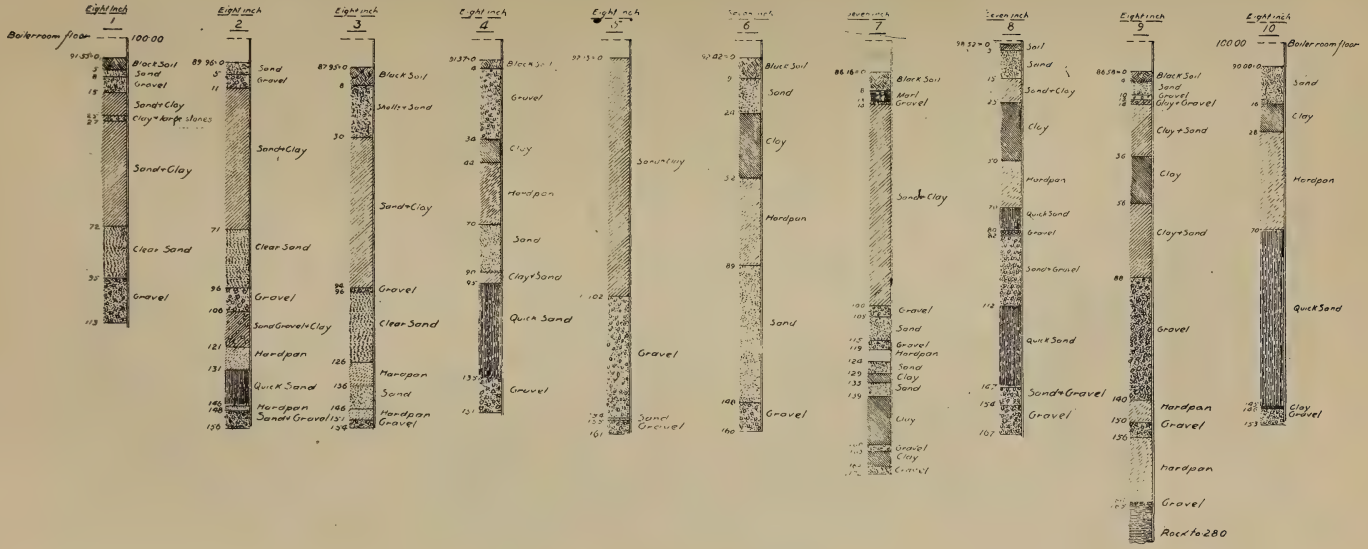
It was also provided that if the quality of water should fail to be that called for by the contract, the hydrant rental should cease until the water supplied be to the satisfaction of the Provincial Board of Health.

Under this contract the Berlin Water Works Company began operations in the spring of 1888. The contract gave them every possible choice in the selection of a water supply, only requiring that it be ample in quantity and of good quality, but the supply chosen lacked both of these essentials. The representatives of the company were taken to see the artesian wells owned by private parties in Waterloo, the large spring near Bridgeport, the Grand river, and other possible sources for a water supply, but they finally decided to dig a well where a small spring bubbled up near the margin of a little pond known locally as Shoemaker's Lake. It was expected that as the well was excavated, this spring would increase and furnish a sufficient water supply, and that the pipe to the lake would only be opened in an emergency as might happen in case of a large fire. The Provincial Board of Health gave their consent to the source of supply, and the company bought an acre of land adjoining the lake for $500, and excavated a large well, but, unfortunately, the spring-water did not increase materially, and the lake water had to be depended upon. From the nature of the surroundings, the lake's muddy bottom and shallow shores, this water was highly charged with organic matter,

BERLIN WATER WORKS

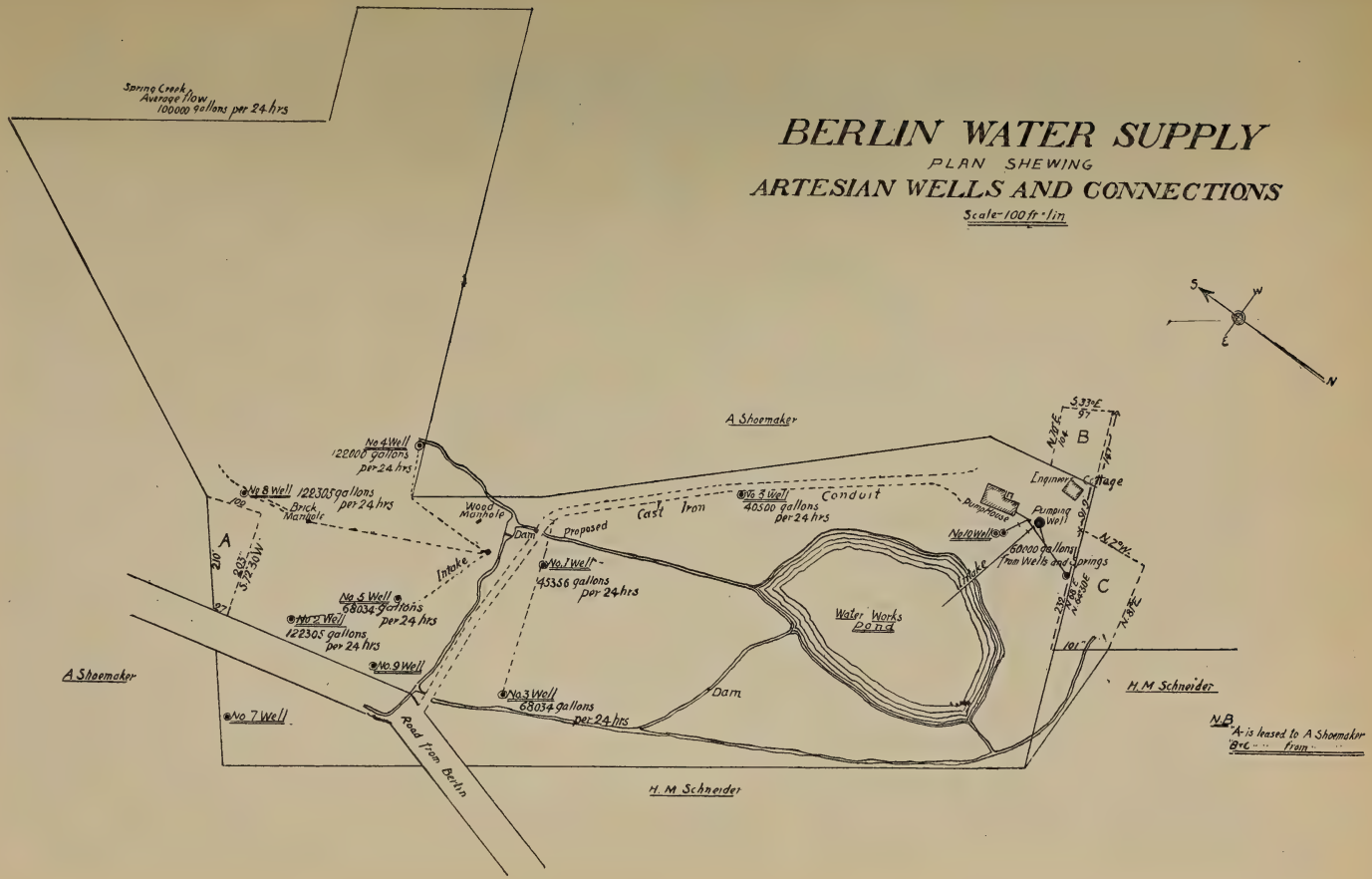
SECTIONS SHEWING STRATA

PIERCED BY ARTESIAN WELLS



and in warm weather was very disagreeable to the taste. However, the works were completed in October, 1888, and after a test by the Town Council as to the efficiency of the fire protection, the hydrant rental began. The supply of water proved sufficient in quantity for the first winter, but as the number of consumers increased and the warm weather coming on the level of the lake began to fall. About a quarter of a mile away and at a higher elevation was a dam supplying power to a small saw-mill. A ditch was dug and the waste water from this was diverted into the lake. In a short time, however, the owner put a stop to this, and the lake was again pumped down until the inlet pipe to the well was exposed. In the meantime, that is, during the summer of 1889, the company had extended the water mains to supply the adjoining Town of Waterloo. As these mains were now complete and the test of six fire streams eighty feet high, had to be made, the lake had to be restored to its old level before the pumps could supply the water. To do this meant the purchase of the saw-mill and water privilege, which was done at a cost of $5,700, including the cost of the land around the dam. It was expected that this outlay would provide an adequate water supply for the two towns for all time to come, but it proved to be only a temporary relief. In 1890 a sewer-pipe conduit was laid from the dam direct to the pumping well, but in hot weather the water turned out to be almost as objectionable as the lake water, and before long the dam was let off and the little creek was made to flow into the lake which was again used to pump from. From this time on the lake was in constant use as a storage reservoir until within the last two years. After the dam was let off it was seen that in the summer one of the little creeks which supplied it went dry, and the other furnished only a very small quantity of water. This is now estimated at only about a hundred thousand gallons per day, part of which is from farm tiles.

To improve the water supply and, as a consequence, the revenue, the company seriously considered building another pumping station at Waterloo, but after a long delay, they decided to try for an artesian well close to Berlin pumping station. This they did in 1896, and were successful, getting a flow of about 200,000 gallons from a 5-in. pipe. This improved the quality of the water very much, and as the prospects of getting other wells near the pumping station were good, the Town Council decided in 1898, at the end of the ten years, to purchase the water works, agreeing with the company to pay $105,000 for the system with supplies, &c. Accordingly, in October, 1898, the


BERLIN WATER SUPPLY
PLAN SHEWING
ARTESIAN WELLS AND CONNECTIONS
Scale-100 fr. to 1 in
Spring Creek
Average flow
100000 gallons per 24 hrs
No 4 Well
122000 gallons
per 24 hrs
No 8 Well
122305 gallons
per 24 hrs
Brick Manhole
Top
A
210'
S 22° 30' W
No 5 Well
68034 gallons
per 24 hrs
No 2 Well
122305 gallons
per 24 hrs
No 9 Well
No 7 Well
A Shoemaker
Wood Manhole
Dam
Intake
Proposed
No 1 Well
43356 gallons
per 24 hrs
No 3 Well
68034 gallons
per 24 hrs
Road from Berlin
H M Schneider
A Shoemaker
Cast Iron
Conduit
No 6 Well
40500 gallons
per 24 hrs
No 10 Well
60000 gallons
from Wells and Springs
Pumping Well
Pump House
Engineers Cottage
Lake
Water Works
Pond
Dam
B
C
S 33° E
97
N 39° E
N 72° W
N 39° E
H M Schneider
N.B. A is leased to A Shoemaker
Bro. from

Town Council began to operate the water works, and in January, 1899, the Water Commissioners took charge. Upon taking office the Commissioners immediately took steps to improve the water supply, and contracted with Fraser & Harvey, of Petrolea, to put down a number of artesian wells. The first well was located between the pumping station and the old mill dam, and at a depth of 113 feet a flow of over 100,000 gallons per day of excellent water was obtained. The next move was to a point between the dam and the road, where a flow of over 200,000 gallons was struck at a depth of 156 feet; this proved to be the best well of all those put down in connection with these works. The diameter of the drive pipe used in this and nearly all the other wells is 8 inches. The water generally comes from a gravel stratum overlying the limestone rock, and is of excellent quality and not as hard as might be expected. With a view of testing the area of the water-bearing district, the Commissioners have since continued the work of boring, nineteen wells having been put down to date, and adding the two wells put down by the company, makes a total of twenty-one wells, costing over $10,000. It was hoped that wells could be got all along the little stream flowing easterly from the water works property towards the town, but the wells at Mill Street, Courtland Avenue and Albert Street, were failures, although carried down into the rock. At Mill Street the rock was struck at a depth of 165 feet, and the drilling was continued to a depth of 323 feet, but only to find strong mineral water and with insufficient head to flow at the surface. Corresponding results were obtained at Courtland Avenue and Albert Street, although the drilling in the rock was not continued so deep. The limit of the water-bearing district has similarly been defined to the north and to the south, but so far has not been reached to the west, and good wells may possibly be found in that direction at some future day.

At the present time about a half million gallons of water per day, by actual measurement, are obtained from the wells in use, and about half this quantity could in addition be had from wells too far away from the present pumping station to be used. So that we have in sight about three-quarters of a million gallons per day of artesian well water, which could no doubt be increased to a million gallons per day if pumping by compressed air were resorted to.

At the present time there are 1,238 water services in the Town of Berlin, a large increase having taken place since the works have come under municipal control, and since the improvement of the

water supply. Of this number 698 are flat rate services and 540 are metered. The policy of the Commissioners has been to encourage the introduction of meters, as this is now recognized as the only sure method of preventing waste of water. Although the number of consumers has largely increased during the past few years, the amount of water pumped has remained about the same, averaging a little less than half a million imperial gallons per day. The use of meters has been objected to by some sanitarians on the ground that sufficient water would not be used to properly flush the plumbing appliances, but this has been guarded against by fixing a minimum rate to meter consumers of $8.00 per annum, thus removing the temptation to be too economical in the use of water. Water is often wasted through defective ball cocks in closet tanks without doing any good, but the meter soon puts a stop to this. Thus our limited supply of water is made to go as far as possible, and the amount of sewage to be treated at the sewage farm is reduced to a minimum.

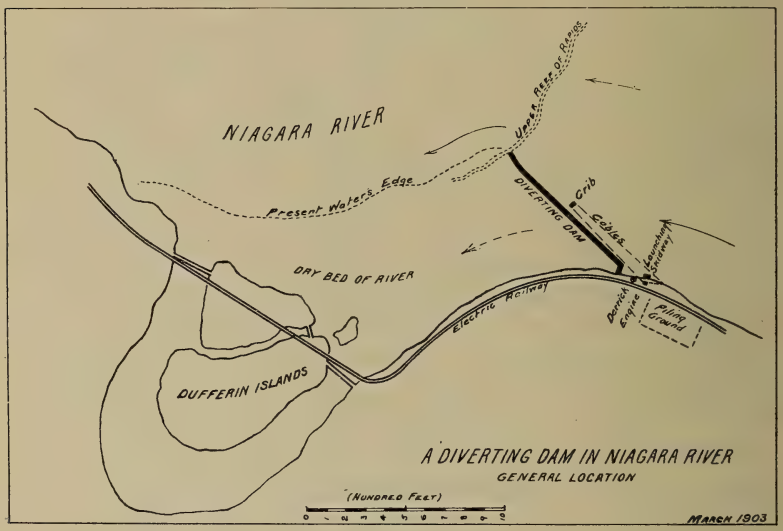
In 1889 our sister Town of Waterloo purchased the water-mains lying in their municipality from the Company, and installed their own pumping plant near the centre of the town. Three seven-inch artesian wells were put down about a hundred feet in depth, and from these about 700,000 gallons per day of excellent water is obtained. In order to locate their water tower on high ground about a quarter of a mile of the main pipe in Berlin was leased at a nominal rental, and the tower was built opposite the Hospital. An agreement was entered into by which either town will supply water to the other in case of an emergency at 3½c. per thousand gallons, and in case of fire both pumping plants can be operated together. So far the valve between the two towns has not been open very often; but once in a while, in dry weather, Berlin draws on our neighbor's supply.

The foregoing will give an idea of the difficulties encountered in getting a sufficient supply of good water for an inland town. The Town of Berlin has now a population of 10,000, and is growing steadily, and the water supply will have to be increased accordingly. For a year or two the Waterloo works can help us out, especially since a large storage well is just being added, but after that we may have to go to the Grand river and install a new pumping plant with the addition of filters. However, the citizens of Berlin are well pleased with the municipal control of the water works, and there is no reason to doubt but that the system will be extended to keep pace with the town without adding a cent to the general taxation.

A DIVERTING DAM IN NIAGARA RIVER.

G. H. Mitchell, B.A. Sc., C.E., M. Can. Soc. C.E.

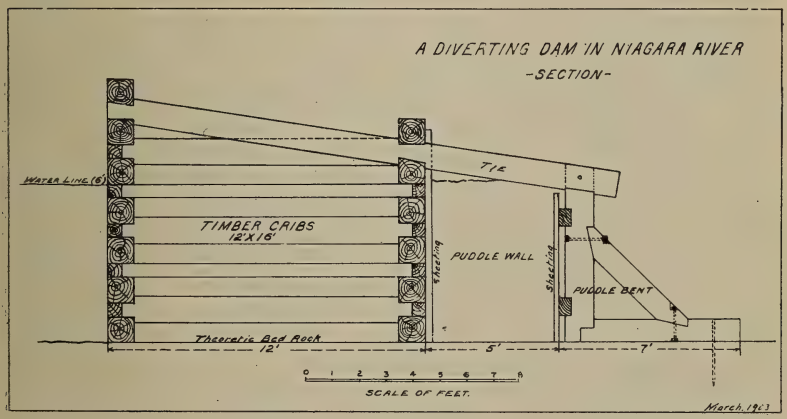
During the autumn of 1902 the writer had charge of the construction of a temporary timber diverting dam constructed in the Niagara river above the Falls, for the Ontario Power Company. As the work in many of its features was unique it will no doubt prove of interest to the members of the Engineering Society.



As is shown in the accompanying plan this diverting dam was constructed at the head of the rapids on the Canadian side of the Niagara river, above the Falls, and at the point above the Dufferin Islands, at the upper end of the Park. The object in its construction was to lay bare that portion of the river bed immediately below and extending around the Dufferin Islands, for the purpose of building the head works of the Ontario Power Company. Owing to the

direction of the river currents and the nature of the rock bed and reefs of the channel, it was determined that a straight dam extending downwards at a slight angle with the current would have the desired effect.

The uncertain features about this work were many and required to be met as it progressed. For instance, no one could tell the depth of water to be encountered out in the river, although several attempts were made to take soundings on the site of the proposed dam. At most the engineers and contractors had to guess the depth of the water before commencing the work. It was unknown also how high the water would bank up in front of the dam by reason of deflecting its course, and consequently it was not known how high at any point



the finished dam would require to be. The speed of the current had been previously determined at several points along the line of the proposed dam, and was found to vary from 10 to 15 feet per second. It was also known that the rock bottom was comparatively smooth and was not strewn with beds of boulders or rock ledges as the surface of the water was comparatively smooth.

The problem to be solved was:—To float a series of timber cribs down the river to the proper points and there sink and load them, or so secure them as to prevent their movement, and build behind them a water-tight wall of clay or other material, and so effectually divert the water from the space below, throwing it out and over the upper reef of the rapids. The total distance from the shore to the reef,

the objective point, was 800 feet. The shore of the river along the point of commencement was protected by a shore crib or retaining wall of timber and stone.

Work was commenced on this structure on August 19th, 1902, and was continued until the end of the year. The first crib was set August 20th, and the last one October 21st.

The first and essential part of the plant for the construction were two high class hoisting engines. One of these was rigged to

Launching a Crib.

the main derrick upon the bank immediately above the commencing point or shore connection of the dam, so placed as to handle timber over the bank and down to the skidway on which the cribs were built. The other engine was anchored on top of the bank in a line with the main face of the dam and was supplied with steam from the derrick engine boiler alongside. This engine was used for operating the steel cables by which the cribs were lowered down the river,

and required to be very strong, sensitive and capable of easy operation. The general idea in the building of this dam was to construct timber cribs on the shore, launch and float them down to the end of the dam already in place, then place them in line, and load them with stone so that they would firmly anchor on the rock bed without slipping. The individual cribs were then secured to each other and made a part of the whole dam by a system of timber ties framed on top so that the upper part of the dam forms a continuous

Crib Afloat; Launching Skidway in Foreground.

bonded structure of cribbing. This done the back side of the cribs was then sheeted with planking, and a second part of the dam consisting of the puddle wall constructed so as to make the dam watertight. The puddle is held in place by means of timber frames or bents and supports for a second row of planking or sheeting.

The accompanying plan shows the details of construction of the dam, in elevation and section, and the map shows the general location of the dam in the river, together with the temporary plant.

The timber for the cribs and sheeting was brought in cars over the Electric Railway and unloaded in the piling yard above the dam. The stone for ballast was for the most part quarried in the dry bed of the river below the dam, and brought up on dump cars on tracks by horses. The clay for use in puddle was obtained very conveniently from the river bank above the electric railway. The special work of constructing and placing the cribs was done by a foreman and gang of nine French-Canadian river men, who are thoroughly familiar with such work. The other labor work was mostly done by Italians.

Crib Ready to Turn End, Looking Down Stream.

The most interesting and critical work was that of lowering and placing the cribs, a fair idea of which can be obtained from the series of photographs accompanying this. In a general way this was carried out as follows:—The crib was built of a size 12 x 16 feet clear, and about 8 feet high, on a skidway along the shore, having a tilting bottom. When constructed, the steel lowering cables were attached and all the tackle of the hoisting engine made ready; the

fall from the derrick was then hooked into the bottom of the skid-way and raised, and when at about 45 degrees the crib slid bodily into the water, having the cables attached. Cables were then paid out until the swift current caught the crib and held it steady. In this position with its face broadside to the current the crib was easily controlled or steered by means of the two cables, one at each upper corner (which would be the upper and lower corners when the crib was in place). The outside (or lower) cable was carried to a block

Crib in Place; Loading with Stone.

anchored to a large tree on the bank and thence down stream along the bank to the engine hoist. The inside cable was carried direct to the engine. By means of these the course of the crib down stream was steered much like a sailboat or current ferry, the inside cable being lowered when it was desired to move the crib outstream, and the outer cable lowered to move the crib instream. By this means the crib was gradually lowered along the outside until near the end of the dam or cribs already placed. This was the critical time.

It is necessary that the upper and inner corner of the crib as being lowered shall just meet and rest on the outer and lower corner of the last crib placed, and when all is ready, turn on this point as on a hinge, the outer cable being slacked away. The crib then slowly swings into its place on the end of the string already placed, and is held firmly by the cables. After being adjusted, if required by jacks, the loading stone or ballast is thrown into the crib, on the ballast floor, thus weighing the section hard on the rock. In this way the

PUTTING ON CRIB SHEETING (BEFORE PUDDLE BENTS.)

whole of the 49 cribs were successfully placed and bonded together. Three other cribs were built and launched, but were lost by accidents, one going over the Falls, and two stranding in the rapids.

The next operation was the sheeting on the inside of the cribs. This was matched 3 inch plank, and was driven home to the rock, spiked on the crib timbers with heavy spikes. Then came the puddle wall bents, as shown in the drawing, consisting of ties to the main cribs and foot pieces anchored to the rock bed by two fox bolts. For

about half the length of the dam these foot pieces were weighted down by rock piled on a ballast floor, to keep the foot from rising due to pressure at the heel. Inside of these bents waling was secured, which in turn carried the puddle sheeting, thus providing a puddle space about 4 to 5 feet wide. This was divided into sections about 32 feet long by light bulkheads, and each section was in turn filled with clay puddle, brought on the dam by dump cars. This puddle, with its sheeting, was carried up to high water level.

Inside as Completed, Looking Up Stream.

When finished there were practically no leaks through or under the dam, although at several points considerable water boiled up through seams in the rock, coming from outside in that way. This water, however, was very easily cared for. As the spring has opened up and the puddle consequently settled, small leaks have manifested themselves, but have been of no consequence and easily repaired. There has not been the slightest trouble with the dam from high water or ice during the winter months.

BY-PRODUCT COKING IN AMERICA.

A. E. Shipley, B.A Sc.

As the handmaid of America's gigantic steel industry the manu facture of coke has in recent years grown to mammoth proportions. The unlimited supply of coal, much of it of a very superior quality for the production of furnace fuel, is one of the foundation-stones upon which the present great industrial expansion has arisen. For the last four years a somewhat peculiar condition has existed in the various coking centres, namely, a race between demand and supply in which the former has kept far in the lead; the result of which is, the price of coke has long soared to such a height that methods of economy are to a great extent lost sight of.

The making of coke consists in the heating of bituminous coal to such a temperature that practically all volatile constituents are separated and expelled in the gaseous form, leaving only the fixed portion consisting of almost pure carbon. This carbon during the process assumes peculiar physical properties, which admirably adapt it to the conditions of a blast furnace fuel, and is known as coke.

On the volatile constituents of the coal, which, under ordinary conditions, are allowed to waste, efforts have been directed for many years, chiefly on the continent of Europe, for their recovery and sale as marketable productions. It is these methods of recovery, known as by-product coking, in their application to American practice, that I have chosen for the subject of this paper, and since the tendency in this class of coking methods has been to economize in labor as well as in production, I wish to use the term in its present wider application of economical coking rather than that of the mere saving of by-products.

The common forms in which the volatile constituents of coal are recovered are: illuminating gas, coal tar, and ammonia; though a variety of other compounds in smaller proportions might be secured. In these forms the product of an average ton of coal is approximately 1,500 lbs. of coke, 9,500 cubic feet of gas, 100 lbs. of tar and 5 lbs. of ammonia.

The production of coke in the United States during 1902 was 23,968,939 tons, of which an estimated 1,143,227 tons were made in by-product ovens, leaving 22,825,712 tons from which no by-products were saved. On a basis of 63 per cent. this represents 36,231,289 tons of coal. We find, therefore, that there were wasted in the manufacture of this coke 334,197,245,500 cubic feet of gas, an amount twice as great as the entire natural gas production of the United States; 1,811,564 tons of tar, 90,578 tons of pure ammonia, besides 4,347,745 tons of coke. These figures, although somewhat misleading, for reasons that will be better understood later on, suggest at once the immense extent of the field for the introduction of the by-product oven.

That progress has not been made in extending its use in America is due to the peculiar trade conditions already mentioned, which have, for the present, overshadowed the prime object of its origin.

In the great Connellsville region of south-western Pennsylvania, where the greater portion of the entire coke product of the United States is made, the facilities for producing coke for the immense steel industries in the Pittsburg district have not at any time, since the present expansion began, four years ago, been able to cope with the demand. It has been a question of how to increase the coke production most rapidly in order to secure the greatest profits from the abnormal price; and as the percentage profit from by-products is inconsiderate, compared with that from the coke alone under such conditions, the simple and quickly erected bee-hive oven, being admirably adapted to meet these important demands, has had the field practically to itself. Great banks of these ovens are being hurriedly built and put into operation. This state of affairs, however, being out of proportion, cannot last, and it is but a matter of time until the production overtakes the demand, and then the price of coke, following natural laws, must drop, and the profit once more become a fraction of the cost of production. Then, as in Germany, Belgium and France, the cradle of by-product coking, attention will be turned to economy and the saving of waste products, and it is altogether probable, in the light of America's well known habit of taking first place in all industrial enterprises, that before many years the by-product oven will supplant the greater number of bee-hive plants recently erected in the Connellsville region.

Meanwhile, however, the by-product oven in this country has by no means languished. Since its introduction eleven years ago a large

number of plants have been erected; and these, scattered widely throughout the continent, are daily proving their ability to cope with the most varied conditions, and will no doubt form the nuclei for a general introduction. Some of the more important types are undergoing a radical change, to suit them to the conditions of American construction, while labor-saving appliances are being added wherever possible. This transition period over, it may no doubt be possible to conform with the ideas of a certain firm manufacturing pipe fittings, who evidently had but a vague conception of a coke oven, and, when applied to for quotations on certain accessories to an oven plant, replied giving the desired information, and adding that a considerable reduction would be allowed on an order for the fittings for a gross of such coke-oven plants.

The by-product coke oven originated in France half a century ago, and after an unimportant experimental career of thirty years, in which various types were developed and tried in that country, as also in Belgium and Germany, it suddenly took root as a commercial enterprise in the latter country, and has undergone a remarkable development; the poor quality of coal and the narrow margins of profits being incentives for its general adoption. In England, owing to an adverse but mistaken criticism of the great ironmaster, Sir Lowthian Bell, made many years ago in regard to the quality of the coke produced, there has been but little progress made in by-product coking; while America failed to recognize any advantages over the antiquated bee-hive system, in common use, until a decade ago. Before dealing further with the subject, however, it will be well to review briefly the coking and gas industries, from a combination of which the by-product systems have been evolved.

History has preserved for our information records of but few of the preliminary investigations and experiments which resulted in the birth of these two most useful industries. They have both sprung from the efforts of the English ironmasters, of the seventeenth and eighteenth centuries, to discover a blast furnace fuel to take th e place of charcoal, the scarcity of which, owing to the very rapid depletion of the forests, had so badly crippled the iron industry that there were fears of its becoming extinct on the island.

Bituminous coal was tried, but without success, until, in 1735, Darby, of Coalbrookdale, in Shropshire, by treating it to a charring process similar to that used in the manufacture of charcoal from wood,

produced a fuel giving fairly good results. For a few years its use was looked upon with more or less disfavor, but by 1750 these prejudices having been dispelled, coke became the chief furnace fuel; and England, in consequence, experienced that remarkable revival in her iron production which has since proved so important an element in her greatness. The original method of coking was patterned after the charcoal process, the coal being formed into heaps and covered with a thick coating of earth to prevent the ingress of air. The air necessary for supplying the required combustion entered through small openings controlled by the attendants. This crude method known as coking in heaps, is still used in some districts, and was even resorted to but recently in the Connellsville region in the desperate effort to meet excessive demand where the existing oven capacity was inadequate. Improvements in the methods of coking took the form of a permanent brick or stone covering in place of earth; permitting a better regulation of the air supply, and thus preventing an unnecessary waste of coal. These kilns, or ovens, have generally assumed a dome-like form, which has suggested the name of bee-hive. With the coking industry established it was not long before attention was drawn to the nature of the flames emitted from the heaps or ovens during coking. In 1786 Lord Dundonald carried on some experiments at his coking ovens, in which he collected the unburned gases and afterwards burned them.

These experiments do not mark the beginning of gas lighting, however, as more than a century before Dr. Clayton had observed that a combustible gas was evolved in the decomposition of coal by heat, but it is probable that they led to Murdock's invaluable investigations, which resulted in the establishement of the gas lighting industry. Murdock, the ingenious English mechanic, with whose early attempts at steam locomotion we are familiar, had had his attention drawn to the inflammable gases given off from coke ovens, and his practical brain saw in them a new illuminant. His ingenuity overcame all difficulties, and he finally produced a gas plant with which he lighted his dwelling. In 1798 the engine shops of Bolton and Watt, in which Murdock was employed, were lighted by a similar plant, and shortly afterwards gas illuminating of the streets of London was begun. By 1815 Paris had adopted gas lighting, and from this date on its use became general.

In its earlier stages the gas lighting industry parted company with that of coking, and although a quantity of coke was regularly produced

in the gas retorts, its quality rendered it useless as a furnace fuel. Each wasted that which the other sought to produce, and for half a century this independent waste continued unchallenged. In the early development of gas lighting the main obstacles lay in the large amount of tarry matter driven off from the coal by the heat of distillation, which, condensing in their passage into cooler environments, quickly choked the gas pipes. Other objectionable constituents of the evolved gases were non-inflammable gases, such as carbonic acid gas and nitrogen, which existed as a diluent, and those, such as ammonia, cyanogen, and hydrogen sulphide, which had an injurious effect on the pipes or produced injurious or poisonous fumes on being burned. The discovery of methods for the elimination of these objectionable constituents was the task of the early gas engineer. This he early succeeded in doing, and in so thorough a manner that but little change has been made over his methods during the last three-quarters of a century. The apparatus thus devised consisted of, first, a condensing and washing system where the products of distillation were cooled down to normal temperature immediately on leaving the retort, causing all the heavier hydrocarbons to condense at once in the form of tar, and where the remaining gas was brought into intimate contact with cold water, which absorbed from it practically all the ammonia compounds; and, second, a purifying system where by chemical means the greater portion of the objectionable gases were removed.

The tar and ammonia removed in this way as objectionable and waste matter soon proved themselves valuable by-products; chemists discovered in the former a source of an innumerable variety of useful hydrocarbon compounds, which have entered into the economy of manufacturing industries, while the latter became a cheap base for the production of the ammonia compounds of commerce.

Although the evolution of tar and ammonia from the coking process was known to the earliest coke makers, the foundation of our modern by-product coking industry was laid in 1856 by Knab, who in that year built a group of retort ovens in France, with the object of producing coke, gas, tar, and ammonia. These were long narrow-arched chambers of refractory brick, 23 feet long, 6 feet $6\frac{3}{4}$ inches high, and 3 feet $3\frac{1}{3}$ inches wide, with tunnels beneath the floor for the application of the heat necessary for the carbonization of the coal.

An improvement on this oven was made in 1862 by Simon and Carves, also of France, by the addition of flues in the side walls, thus

increasing the heating surface of the oven. They also added the condensing and purifying apparatus for the gas, as in gas works, and provided for the extraction of ammonia and tar.

This oven with certain improvements was introduced in 1881 into Germany by Huessner.

In the meantime the retort oven without by-product appliances was being developed in Belgium. This was due to its adaptability to labor-saving appliances, and was found to give satisfactory results on the poor Belgian coals. This type of oven, built in groups or batteries with long narrow coking chambers, discharged its gas from the top of the oven into flues passing down the side walls, where, meeting with a supply of air admitted for the purpose, combustion took place. This provided the necessary heat for the coking operation.

A modification of this oven, known from its originator as the Coppee, is one of the most popular of non-by-product retort ovens today. In the earlier Belgian ovens experiments were begun with mechanical devices for the eliminating of labor, resulting in a mechanical pusher or ram, which, passing through the arched oven chamber, drew or forced the finished charge of coke from the oven. Besides the saving of labor, this operation decreased the time of discharging, so that the oven could be recharged with but little loss of heat to the side walls. This mechanical method of pushing or discharging is now used in all retort ovens.

In 1831 an improvement on the Simon-Carves oven was brought out in France by Seibel. This oven, by the use of horizontal flues, was able to maintain a much higher temperature.

About this time attention was directed to the production of a better class of coke in retort ovens, and efforts were made to overcome their inherent defects. It was found that the size and shape of the oven had an important effect on the quality of the coke product. A gradual narrowing down of the oven chamber resulted, until a width of from sixteen to eighteen inches has been fixed as the most satisfactory. With an oven of this width results closely approximating that of the bee-hive oven with the best coals have been obtained.

In 1881 Dr. Otto & Co. evolved a new type of oven in Germany. This oven had vertical flues arranged to give a better distribution of the heat from the burning gases, and two years later was further improved by Gustave Hoffmann by the addition of the Siemens regenerator. In this form, known as the Otto-Hoffmann oven, it has met with

marked success in Germany; and in America, with certain modifications, it has outstripped all other types of retort or by-product ovens in the extent of its application.

The Semet-Solvay oven was introduced in 1882 by the firm of Solvay & Company of Brussels. It is a retort oven with by-product appliances, and the primary aim of its originators was simplicity of construction. It involved the use of special shaped tiles and fire brick in an effort to secure thinness of conducting walls between the flues and coking chambers. It lacks the regenerator of the Otto-Hoffmann system, but this loss is partly made up by the employment of a continuous recuperative process. This oven is also meeting with great success in Europe, while in America it is the only important competitor of the Otto-Hoffmann.

Reviewing briefly the growth of the by-product coking industry, we find that it had its inception in the coke and gas works in England, it took form and passed thirty years of an experimental career in France without attaining any degree of commercial importance. A more complete development of the plain retort oven took place during the same period in Belgium. It was not until twenty years ago, however, that the Germans, improving on the French types, brought the by-product oven into general use. The English and Americans have lagged ten years behind, owing, perhaps, to their better class of coals and to an absence of that spirit of frugality characteristic of the Germans. During the last decade the by-product coke oven has found its way into the majority of industrial countries.

The first by-product ovens erected in America were a small group of twelve ovens of the Semet-Solvay type, built by the Solvay Process Company at Syracuse, N.Y., in 1891, with the object of obtaining coke and ammonia for their soda manufactory at that place. In these ovens were tested samples of coal from the various mines throughout the United States and Canada, and the results proved very satisfactory indeed. This plant has since been increased to 40 ovens.

In 1895 the second coke oven plant of the Solvay type was constructed for the Dunbar Furnace Company at Dunbar, Pa. This plant of 50 ovens was built in the heart of the Connellsville coke region, and commenced operations in the autumn of 1895.

It was at the Cambria Iron Works at Johnstown, Pa., that the Otto-Hoffmann oven began its career in this country. Situated on the

western slope of the Alleghanies, and operating a very extensive furnace plant from the inferior coals of that district, the Cambria Iron Company was unable to produce a satisfactory coke in the ordinary bee-hive oven, and was in consequence forced to investigate other methods of coking. The Belgian oven was, many years ago, tried on an extensive scale with favorable results, and in the course of time this was supplanted by the more improved Coppee type. Shortly after the erection of the Semet-Solvay plant at Syracuse, representatives of the Cambria Company, who had been sent to Europe to investigate the various methods of coking in use there, reported in favor of the by-product system. A contract was in consequence awarded to the United Coke and Gas Company, controlling the American patents of the Otto-Hoffmann oven for the erection of 60 ovens at Johnstown. This plant was provided with by-product appliances, and commenced operation in the spring of 1896.

These two plants built by the two rival American companies exploiting the by-product systems were the pioneers in supplanting the bee-hive oven in the manufacture of furnace coke; and that their work has proved satisfactory is shown by the additions that have from time to time been made on them. The Semet-Solvay plant has since been more than doubled, and now consists of 110 ovens. The Otto-Hoffmann plant at Johnstown was, in 1898, increased to 120 ovens, and there are under construction at the present time 100 more, with provision for 300 additional ovens in the near future.

Since the construction of these two plants the progress of the by-product oven has been steady, although by no means rapid. Following closely on the completion of the Dunbar plant the Semet-Solvay Company erected for the Sharon Steel Company, at Sharon, Pa., a plant of 25 ovens for the manufacture of metallurgical coke. Two years later, in 1897, a plant of 60 Semet-Solvay ovens was built for the Riverside Iron Works at Wheeling, W.V., later being increased to 120 ovens.

During same year 120 of these ovens were built for the Tennessee Coal, Iron and Railroad Company for the production of blast furnace coke; this plant, located at Ensley, Ala., has since been doubled. In 1898 a ten-oven Semet-Solvay plant was built to supply the city of Halifax, N.S., with heating and illuminating gas, the coke finding a market for domestic consumption. Last year a plant of 120

ovens was put into run at the Solvay Process Company's works at Detroit, Mich., the object being similar to that of the Syracuse plant.

The Semet-Solvay Company have at present under construction four small plants; one of 80 ovens at Milwaukee, Wisconsin, another of 40 ovens at Chester, Pa., and a fourth of 90 ovens at Labanon, Pa.

The Otto-Hoffmann system under the control of the United Coke and Gas Company, has met with an even greater measure of success, the difference being in the relative size of the plants rather than in their number. The second Otto-Hoffmann plant was erected at Glassport, Pa., in 1897, for the Pittsburg Gas and Coke Company, for the production of furnace and domestic coke, the gas being used as fuel. In 1898 the 400-oven plant of the New England Gas and Coke Company at Everett, Mass., went into run. This plant, at that time the largest and most complete on the continent, was a financial undertaking with an object quite the reverse of that usually underlying other plants. In fact, it stands to-day as the only instance, on this side of the Atlantic at least, where the by-product coke oven has been exploited on its merits as an independent commercial enterprise. All other plants have been constructed as subordinate to some more important industry to which one or more of the coke oven products are essential, the remaining residuals constituting the by-products. In the Everett plant there are no by-products, strictly speaking, as no particular product is especially desired; the entire output of the plant being sold in the best available markets. The coke finds a sale as smokeless locomotive fuel, as well as for domestic and factory purposes. The gas is sold for illuminating purposes in the vicinity of Boston, the tar and ammonia are disposed of to chemical manufacturers and other allied industries. In view of the unique features of this plant I shall make it a subject for special description at a later period.

The next plant erected was at Sydney, N.S., for the Dominion Iron and Steel Company, and in size and arrangement is a duplicate of that at Everett, although much less complete. The coke, gas, and tar are all used for fuel; the two latter in the open hearth furnaces. Like the Everett plant it operates on Cape Breton coal; this plant was put into use early in 1901.

Some months ago an additional 50 ovens of the non-by-product type were added to the plant, and more recently a contract has been awarded to the United Coke and Gas Company for 200 ovens of a special type, to be operated at present without recovery of by-products;

but to be converted later, if desired, to the underfired type of by-product recovery oven. The principal product desired at this plant is metallurgical coke, but if market facilities make it desirable, the by-products may be obtained by slight changes in the ovens, as provided for in the present design.

In 1901 a plant of 50 Otto-Hoffmann ovens was erected for the Hamilton Otto Coke Company at Hamilton, Ohio, for the production of illuminating gas, the coke product being sold for local domestic and foundry purposes.

Early in 1902 a small plant of 15 ovens of the new Schniewind type went into run at Wyandotte, Mich., for the Michigan Alkali Company. This plant has served as a test for the various radical improvements introduced by the United Coke and Gas Company about this period. The last Otto-Hoffmann plant to go into operation is that of the South Jersey Gas, Electric and Traction Company at Camden, N.J., consisting of 100 ovens of the Otto-Hoffmann type.

The Camden plant, although comparatively small, has several important features worthy of special consideration. It is intended to supply illuminating gas to a number of cities in southern New Jersey, principally Camden and Trenton, and is being consequently provided with an extensive enriching system which will provide a uniform candle power. The base of this system is the abstraction of the benzol and other light hydrocarbons from the poor or fuel gas and adding them, when necessary, to the remainder of the gas product intended for illuminating purposes. This is done through the medium of a light oil which has a strong affinity for benzol and its homologues at low temperatures, but parts with them when heated. The cool oil is sprayed into chambers through which the poor gas is forced to flow, and coming into close contact with the gas and its contents of benzol, through the peculiar construction of the interior of the chamber or washer, the benzol is absorbed by the oil. The oil then passes to a still where it is highly heated, while a portion of the rich gas is brought in contact with it. This gas in turn absorbs the benzol, and leaving the still charged heavily with vapors of the latter, is passed into the main stream of rich gas in a proportion sufficient to raise the latter to the necessary candle power. To reduce the cost of an otherwise expensive pipe line a compressor is to be used, and the gas compressed to two atmospheres, forcing it through a 12-inch pipe line as far as Trenton, a distance of 30 miles, the gas then being reduced to normal pressure on entry into the distributing pipe system.

There are a large number of Otto-Hoffmann plants under contract and in course of erection. One of 200 Schniewind ovens for the Maryland Steel Company at Sparrow's Point, Maryland, is nearing completion. In this, as in all of the uncompleted plants, the coke and gas is desired for metallurgical purposes. One of 212 Schniewind ovens, for the Sharon Steel Company at Sharon, Pa., is also nearly ready to begin operations. Two plants, one of 232 ovens of the Otto-Hoffmann type at Lebanon, Pa., and one of 564 Schniewind ovens at Buffalo, are in course of erection for the Lackawanna Steel Company. An addition to the Cambria Steel Company's plant at Johnstown, Pa., of 100 ovens, is in progress, while it is intended in the near future to increase the plant by 300.

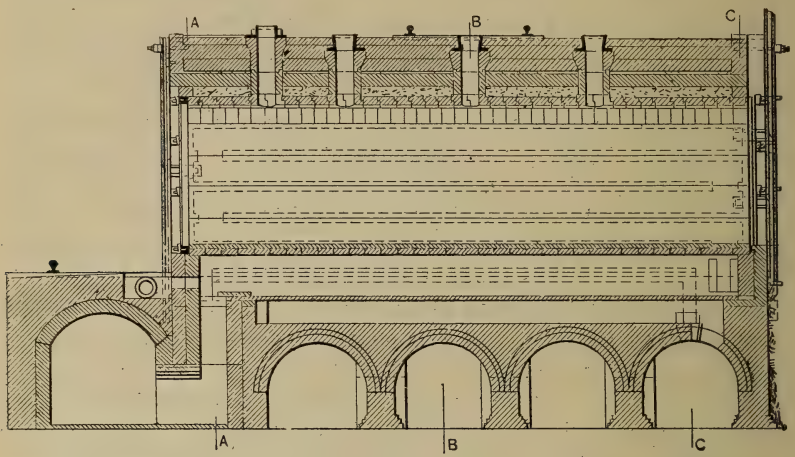


FIG. 1.—LONGITUDINAL SECTION OF SEMET-SOLVAY RETORT COKE OVEN.

Besides these two main types there have been erected at various places throughout the United States and Canada a number of by-product and retort oven plants of American and English design, but as yet none seem to have got beyond the experimental stage. Of these the Newton-Chambers is perhaps the most prominent.

It will be noticed from the foregoing that the development of by-product coking in America has been confined mainly to two of the more important European types of oven, the Semet-Solvay and the Otto-Hoffmann.

The Semet-Solvay system has a number of advantages over its rival, such as cheapness of construction, simplicity in operation and

rapidity of coking; but for general efficiency on large scale operations the Otto-Hoffmann seems to have met with the greater success, judging from its extensive adoption in recent years.

The Semet-Solvay ovens are usually built in batteries of thirty. Figs. 1 and 2 show the method of construction. The ovens are heated by four horizontal flues in each side of the chamber. These flues are heated by the combustion of gas admitted at the ends. The air for this combustion is previously passed through the supporting arches beneath the battery, where its temperature is gradually raised by the waste heat from the ovens above; this arrangement is known as a recuperator and its operation has the advantage of being continuous, although the rise in temperature of the air resulting from its use is much below that produced in the Siemens regenerator.

The products of combustion pass back and forth from end to end of the oven, dropping to the next lower flue as each end is reached, and then enter a central flue beneath the oven floor; this flue collects both streams of gases from the side wall flues and carries them along under the full length of the oven, finally delivering them to the main stack flue. The chief advantage in this arrangement of flues is the excellent control of the temperature of the oven, made possible by the regulation of the fuel gas entering each flue from the end. This temperature ranges from 900 degrees centigrade at the top to 1,100 degrees at the bottom, the middle flues reaching 1,200 degrees. The Semet-Solvay arrangement also permits of easy and thorough inspection. The flues themselves are of refractory tiles of special shapes, and, as the view indicates, are independent of the main brickwork of the battery; this allows of free expansion and contraction, which is excessive where wet coal is charged, and thus prevents strains and rapid cracking of the brickwork. The tile flues are easily replaced without injury to other portions of the battery.

The oven chambers are 30 feet long, 7 feet 6 inches in height and from 16 to 20 inches wide. The ends of the retort are closed with brick-lined cast iron doors, which are made gas tight at their junction with the oven by a luting of clay. The operation of luting the doors is necessary every time they are closed after pushing the charge.

Just above the smoke flue at the end of the oven is shown the fuel gas main which makes connection with the different burner pipes in the horizontal flues. In the top part of the structure are shown the three charging holes through which the charge is dropped into the

oven from a lorry running on rails along the top of the oven; as the coal charged in this way forms into heaps it is necessary to level these down by means of a long bar passed in through an opening in the door. A fourth opening in the top of the oven to the left of the charging holes allows for the passage of the gas to a large collecting main running the length of the battery and making connection through this opening with each oven; a suitable valve being placed in each connection in order to cut out the oven during the charging. Small cover plates or hoods are placed over the charging openings during the coking operation to prevent leakage of gas.

The ovens are discharged by means of a pusher or ram operated by electricity, and the charge falls into an inclined platform moving

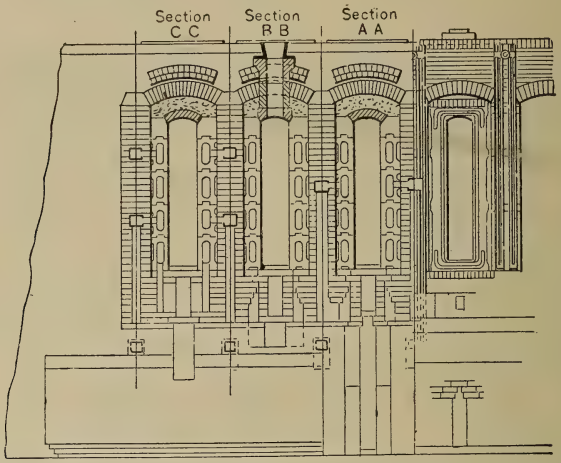


FIG. 2.—TRANSVERSE SECTION OF SEMET-SOLVAY OVEN, REFERRED TO LONGITUDINAL SECTION ABOVE.

on rails on the opposite side of the battery, where it is quenched and finally allowed to slide by gravity into railway cars. The ovens are usually provided with an automatic door hoisting apparatus.

With good coal the coking time ranges from 18 to 24 hours. The condensing and purifying apparatus for the gas is similar to that of all gas plants, and need not be described here as the general method will be outlined later in a description of an Otto-Hoffmann plant.

The Semet-Solvay Company own and operate all their plants, selling the coke and gas to the various furnace companies for whom they were built to serve.

The modern type of Otto-Hoffmann oven as built in America is shown in the two sectional views, Figs. 3 and 4.

It retains the general features of the old Otto-Hoffmann oven, but differs radically in the method of support, and in the manner of feeding the fuel gas to the combustion chambers. The substitution of structural steel for concrete in the substructure of the battery is one of the many improvements made by the United Coke and Gas Company during the last two years. This method of construction was originated by Dr. F. Schniewind, and by its use are eliminated a num-

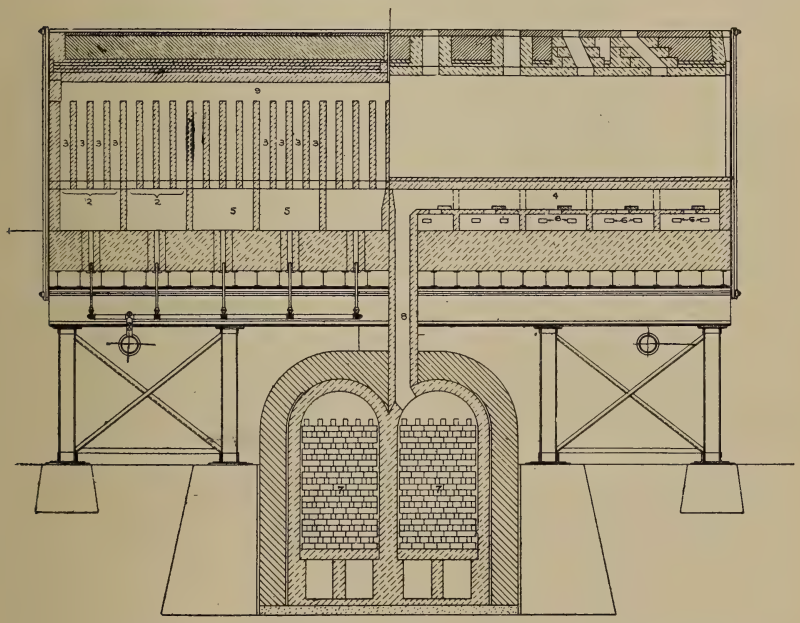


FIG. 3.—CROSS SECTION THROUGH FLUES. CROSS SECTION THROUGH OVEN.

ber of serious defects characteristic of the older ovens. The chief advantage lies in permitting a complete regulation of the fuel gas to the various sections of the flue system, by means of which the coking process may be rendered perfectly uniform throughout the oven chamber. It also allows a more thorough inspection of the oven brickwork, as well as that of the regenerator. The effects of expansion and contraction, due to the constant change of temperature in the regenerator, are rendered less destructive to the battery structure.

The ovens, as in all retort types, are grouped together in batteries. The number so grouped depends upon the nature and capacity of the plant. In the earlier plants of this company 50 ovens were included in each battery, but at present the number is increased or diminished to suit each particular case.

Coincident with the changes just mentioned there has been a lengthening of the oven chamber of over ten feet, providing an increase of one-third of the coking capacity with but small additional cost for construction, while the efficiency of the oven is materially raised.

The coking chamber is 43 feet 6 inches long, 17 inches wide, and 6 feet 6 inches high. Fig. 4 shows a longitudinal view of a portion of a battery of this type of oven. In the elevation are shown the ends of the oven chambers with the removable doors in position. The sectional view clearly indicates the internal arrangement of the ovens, the heating flues, and also the regenerators. The two arched regenerators placed centrally beneath the battery, and running its entire length, perform the function of heating the air supply of the combustion chambers.

The retorts or coking chambers, 1, are separated by hollow fire-brick walls through which the combustion gases pass. These are divided by vertical partitions into ten compartments, 2, each of which contains four vertical flues, 3. Directly under each retort, and communicating with the regenerators, 7; through the fire-brick pipe, 8, is an air chamber or flue, 4, which connects through the openings, 6, with the combustion chambers, 5, on either side. These combustion chambers, ten in number, are formed at the bottom of each flue compartment between the retorts. In the floor of each is a circular opening for the gas burner, which is connected by piping to the fuel gas main. The air and combustion chambers are divided by a partition in the centre of the oven, but allowing communication between the two portions above the vertical flues. The action of this system is as follows:

Heated air from the regenerators, forced by a fan or blower, passed upward through the pipe, 8, into the air chamber, 4, on the right-hand side of the battery; thence it passes through the openings, 6, into the combustion chambers, 5, on either side; in each of these it meets a stream of gas from the burner pipe and combustion takes place. The intensely heated products of combustion rise through the

vertical flues, and pass along the top flue, 9, to the left-hand side of the battery, where they distribute themselves and pass down the various flues on that side to the combustion chamber beneath; then they flow through the openings, 6, to the air chambers, 4, and down the pipe, 8, to the left-hand regenerator. Here they give up much of their remaining heat to the firebrick checkerwork, to be taken up by the cold

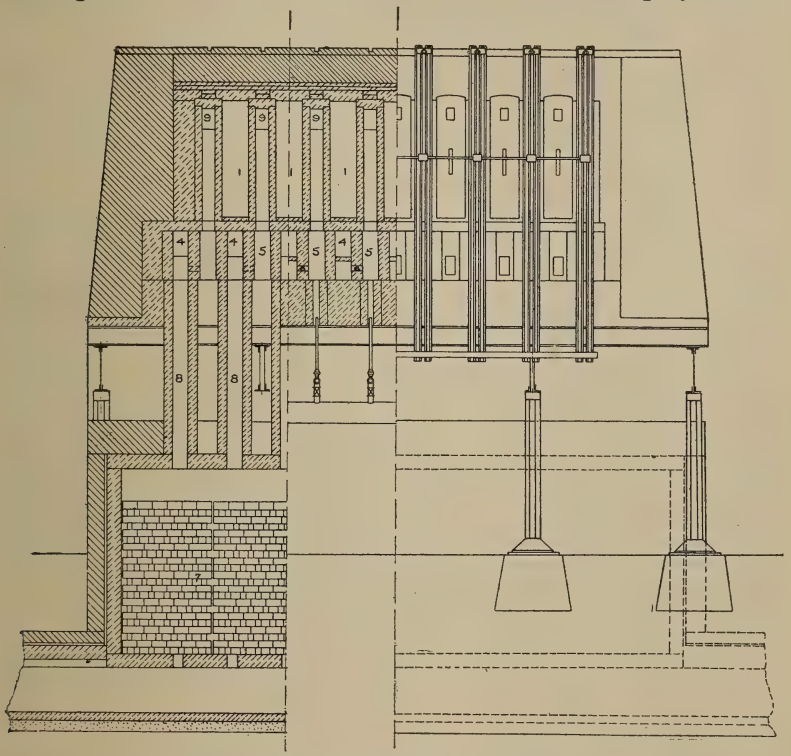


FIG. 4.—LONGITUDINAL SECTION. ELEVATION.

air on reversal. After passing through the regenerator they flow to the stack. By means of valves in air and fuel gas mains the operation of combustion is altered from one side of the oven to the other, and the direction of the air and products of combustion reversed; this being a necessary feature of the Siemens regenerator. The air is heated to a temperature of 1,800° F. before it reaches the combustion chambers, resulting in the production of very high temperatures within the coking chambers and effecting a great saving of fuel gas.

Reversals of the combustion system are made about every 30 minutes. In some of the more recent plants the horizontal regenerator has been replaced by the ordinary blast furnace stove.

As in the Semet-Solvay oven, the charge is dropped into the oven through openings in the top; the number of these openings in each of the new type of oven is eight. The two openings at either hand, serving also as the gas outlets, connect with the two collecting mains through a goose-neck connection in which is a cut-out valve. Two collecting mains are employed only where the gas is used for illuminating purposes; the object being to separate for fuel purposes the later gaseous product of the charge, which is low in illuminating power, from the earlier portion; this is done by the valves in the connections from the ovens to the mains.

The ovens are charged in the usual way by a larry shown in Fig. 6, which receives its load from the bunker between the batteries. Fuel gas is supplied to the burners through two mains running beneath the battery and supported by the steel structure. A pusher, 22, discharges the coke into a loader, 20, on the opposite side of the battery, where it is quenched and afterwards dumped into cars. This open air quenching is perhaps the only condemning feature in the retort system, as it results in an excess of moisture in the coke, which is far from desirable. It also destroys to a considerable extent the silvery appearance characteristic of good bee-hive coke where the quenching is performed within the oven. Lately the United Coke and Gas Company have been making efforts to overcome these evils of quenching the charge outside of the oven, and have developed an apparatus which is to be used at some of the later plants.

Electric door hoists are employed on a new type of self-sealing door which has been introduced, which dispenses with the laborious, and, to say the least, crude method of clay luting, as heretofore employed, reducing materially the cost of labor in operation.

A stack is usually provided for each pair of batteries, while a fan is used to force the necessary air into the regenerator, and the regulation is such that the pressure of the heated air at the period of its passage around the oven walls on combustion is as nearly atmospheric conditions as possible. This is to prevent any tendency of the air to enter the oven, the interior of which is also maintained at normal pressure, through possible cracks in the brickwork, thus avoiding the possibility of explosions or unnecessary burning of the gas or coke within the oven chamber.

I shall now briefly outline the arrangement and operation of a plant of 100 by-product ovens equipped for the production of illuminating gas of uniformly high candle power, as designed by the United Coke and Gas Company, a plan of which is shown in Fig 5. The ovens, which are of the Schniewind type of Otto-Hoffmann ovens, are arranged in two batteries of 50 ovens each. Between the two batter-

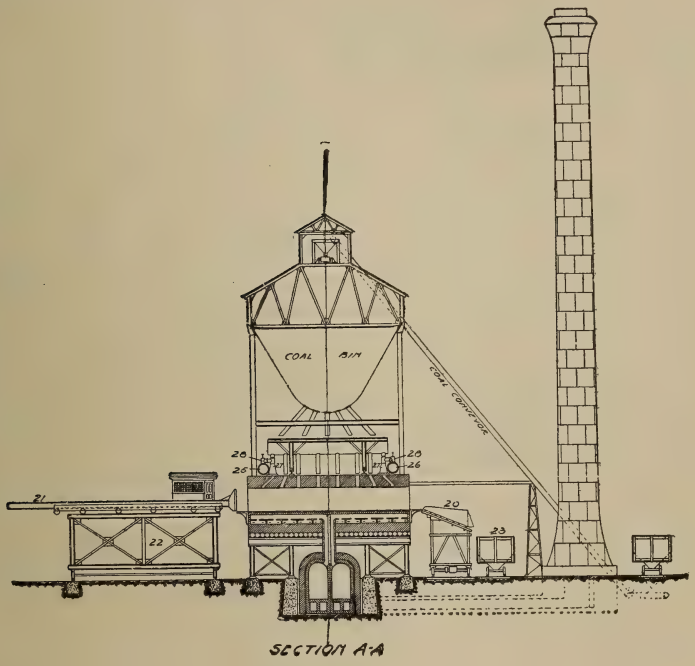


FIG. 6.

ies is a coal bin of sufficient capacity to hold a two-days' supply for the plant. This bin is fed by an inclined conveyor or elevator from a track pit into which the cars of slack coal from the mines are dumped, which arrangement is clearly shown in the sectional view, Fig. 6. Under the bin are a number of spouts, by means of which the charging larry passing underneath is uniformly filled. The charging larry is also provided with spouts, eight in number, so spaced that each, as the larry travels along the top of the battery, comes directly over a corresponding charging hole in the top of the oven. The track upon which the larry runs is continuous along the battery tops and

under the bin. When an oven in either battery is to be charged the larry is run under the bin, where it receives its load of coal. It is then run over the battery until the oven to be charged is reached, the covers of which have been previously removed. The charge is dropped through the spouts into the ovens, where it is levelled down by means of a long rod inserted through an opening in the oven door. As soon as the charge in the larry is moved away, the covers are placed over the charging holes, the gas valve, 28, leading to the rich gas main, 26, is opened, and the coking process begins.

In a plant of this size making 24-hour coke the operation of pushing and charging takes place at different points along the batteries at intervals of 15 minutes. To preserve as uniform conditions as possible, with regard to the distribution of the heat within the battery, a regular system of rotation in pushing the ovens is followed, such that each pair of contiguous ovens is twelve hours apart. The gas is allowed to flow into the rich gas main for a period governed by the amount of poor gas required for heating the ovens, after which the valve is closed and that opening into the poor gas main, 25, on the left side of the oven opened; this gas, which is gradually dropping in illuminating power, continues to flow into the poor gas main until the coking process in the oven is finished; when this occurs the valve, 28, is closed, cutting the oven out from the remainder of the plant. The doors are hoisted and the pusher, 22, which has been run opposite the oven, is brought into operation. The ram, 21, passing through the oven, drives the prism of coke out at the opposite end; a stream of water directed from a hose nozzle is turned on the coke, as it emerges from the oven, to quench at once the heat in order to prevent loss from burning, and to allow its immediate discharge into railway cars. The coke is received on a loader, 20, from which it is dropped into the cars.

Immediately on leaving the highly heated oven the heavier hydrocarbons in the gas begin to condense out in the collecting mains to form tar. The rich and poor gas mains conduct the gas and condensed tar to the condensing plant shown on the lower half of the plan. In their passage through this system the two streams are kept distinct, though for emergency purposes, a series of by-pass connections allows a variety of combinations over the ordinary method of treating the gas. The object of the condensing plant is to lower the temperature of the gas to approximately atmospheric conditions, in which operation the tar condenses, and the greater portion is removed.

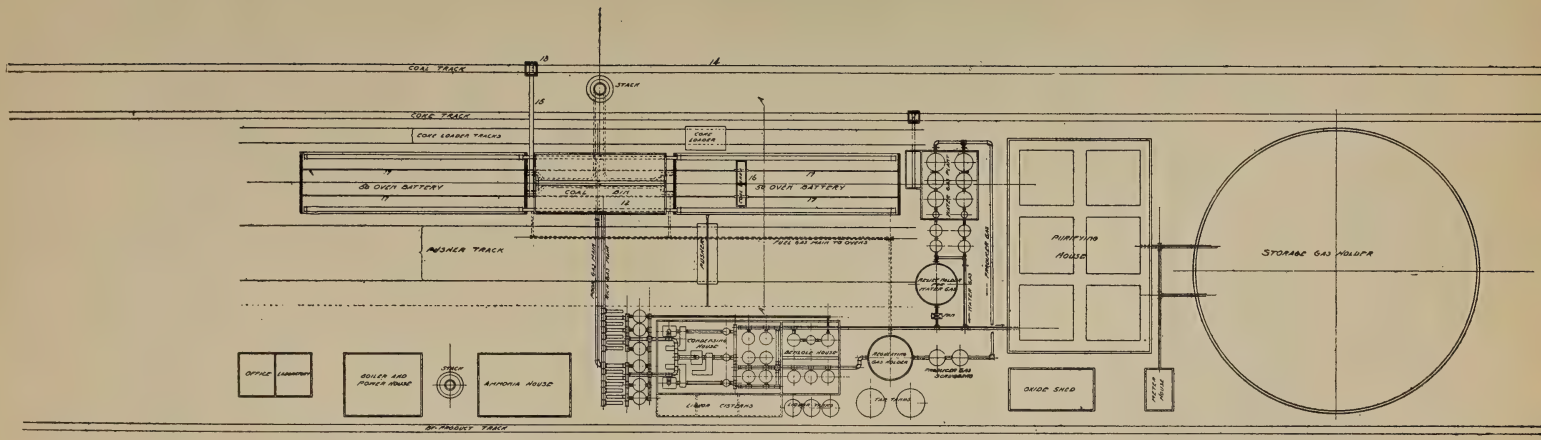


FIG. 5.—GENERAL PLAN OF BY-PRODUCT COKE-OVEN PLANT FOR THE MANUFACTURE OF ILLUMINATING GAS.

The gas first enters a set of air coolers in which it is made to circulate in finely divided streams through comparatively small tubes, placed in the open air in such a position that there is a good current of cool air playing around them; from these the gas enters a set of multitubular coolers, through the tubes of which cooling water is circulated. The gas passes in series through this set, spreading out among the water cooled tubes in its passage. At the outlet of the water coolers the gas contains still a small residue of tar in the form of finely divided globules carried in suspension. To free it of this it is passed through an extractor composed of a system of baffle plates of finely perforated sheet metal, in which the speed of the gas may be so regulated as to give the best results. The tar formed in the gas mains, coolers and extractors, together with a small portion depositing at later stages, is led to a collecting cistern. From here a portion is pumped back to the batteries and injected into the collecting mains for the double purpose of flushing the latter and of allowing the hot gas to absorb the benzol and other light hydrocarbons contained in the tar, thus raising materially the candle power of the former.

After leaving the tar extractor the gas enters the exhauster, the purpose of which has been already stated. The exhauster is of the ordinary rotary type, and is driven by an engine or motor. The slight compression of the gas by the exhauster has the effect of materially raising the temperature of the former, which is cooled again by a passage through a small second cooler.

The gas now passes in series through a set of scrubbers, the purpose of which is to separate the vapor and salts of ammonia from the gas; the solubility of the former in water is the principle on which this process is based. The scrubbers consist of large steel cylinders filled with a great number of wooden gratings over which water is caused to trickle, giving a very extensive wetted surface exposure to the gas in its passage through the gratings. The water is made to travel in an opposite direction to the gas; so that the fresh water, with its great affinity for ammonia, meets the gas containing the least. The water used in the last scrubber is passed through the second and finally the first, where it meets the incoming gas most heavily charged with ammonia. The water having absorbed about one per cent. of ammonia is now known as ammoniacal or gas liquor. It is drained from the scrubbers into a cistern from which it is pumped to the ammonia house to be transformed into marketable products.

Up to this point the poor and rich gases have passed through duplicate sets of apparatus, and have received the same treatment.

Referring to Fig. 5, the two mains are seen entering the benzol house; the poor gas on the right and the rich gas on the left; here their similarity of treatment ends.

The poor gas is passed in succession through three benzol scrubbers, precisely as in the ammonia scrubbing system, excepting that instead of water, a light oil from the distillation of tar is employed. This oil when cold has a strong affinity for benzol and its homologues, and in its contact with the poor gas absorbs what candle power the latter may have in the form of these light hydrocarbons.

The poor gas, freed from its benzol, passes to the fuel gas holder, and thence back to the oven batteries to be consumed in heating the ovens.

The tar oil, saturated with benzol from the poor gas, is heated in a pair of stills, shown to the left in the benzol house. The benzol, liberated from the tar oil by means of the heat, passes over in vaporous form, and is then mixed with the rich gas to raise its candle power. The rich gas now passes to the purifying beds and thence through the meter to the distributing gas holder. A producer gas and also a water gas plant are added as auxiliaries, the former to supply a cheap fuel gas for the ovens when it is desirable to obtain more rich gas than the requirements of the fuel system will allow from the oven production; the latter to produce a cheap diluent where the richness of the gas and the available benzol permit of its use. These two plants are fed with waste coke and coal unfit for sale or other use.

The ammonia house, shown to the left of the plan, contains the apparatus for working over the gas liquor. This includes an ammonia still of the Feldman type, having fixed and volatile sections with liming chamber; in this the hydrated ammonia and volatile salts are broken up by the heat of direct steam, while the fixed salts are treated with lime and subjected to a heavy boiling process. The ammonia vapors pass out the top of the still, where it is allowed to give up its surplus heat to the incoming gas liquor by the use of an economizer or preheater.

Two forms of marketable ammonia are made: the sulphate and 16 per cent. liquor or aqua ammonia. In making the sulphate the ammonia vapors leaving the still are caused to bubble into a solution of sulphuric acid, contained in a lead lined tank called a saturator. When all the acid is neutralized the contents of the saturator are run into a cooling tank, where precipitation takes place. The saturator, in the meantime, is recharged with acid and mother liquor. When

precipitation of the sulphate is complete the mother liquor is siphoned off to be used again in the saturator; the precipitated sulphate is then dropped into a centrifugal drying machine, which frees it of mother liquor. The sulphate is finally stored in bins to be bagged and shipped when suitable.

The manufacture of ammonia liquor involves less labor; the vapors from the still are passed into a concentrator or condenser, consisting of a series of water cooled compartments, which cool the vapors down until absorbed by the water driven over from the still.

The most extensive and complete of the earlier American by-product plants is that of the New England Gas and Coke Company at Everett, near Boston, Mass. It formed a link in the chain of gigantic enterprises founded by Henry M. Whitney, and was designed with the object of providing a market in Boston for the output of the Dominion Coal Company's mines in Cape Breton, Canada. The coal is brought from Louisbourg, C.B., by the coal company's fleet of steamers and unloaded into bunkers on the wharf.

Fig. 7 shows a general view of this plant. Two rows of four batteries of fifty ovens each form the basis of the plant. Between these are shown the producer house, condensing plant, power house, ammonia distillery and the various stacks for the ovens. Between each pair of batteries is a high coal bunker from which the coal is fed into the ovens by means of a larry traversing the top of the batteries. This larry, which is driven by electricity, receives its charge from the elevated bunker; it then moves over the oven to be charged, and the contents are dropped through several spouts into the charging openings in the top of the oven. The transportation of the coal from the bins on the wharf to the four distributing bunkers between the batteries is effected by means of an endless cable railway. The small narrow gauge cars receive their charge from the wharf bins by gravitation; they are then gripped to the cable and start on their journey around the plant. On leaving the wharf bins they ascend an incline to the top of the first bunker, and then pass over at a high elevation to the top of second, and thence down an incline to the rear of the plant.

They then traverse a long trestle under which is the storage heap for emergency use, rising again to the top of the third, and thence pass to the fourth bunker, after which they drop down an incline to the wharf bins; thus making an entire circuit of the plant. The cars are dumped while passing over the bunkers or over the trestle at the

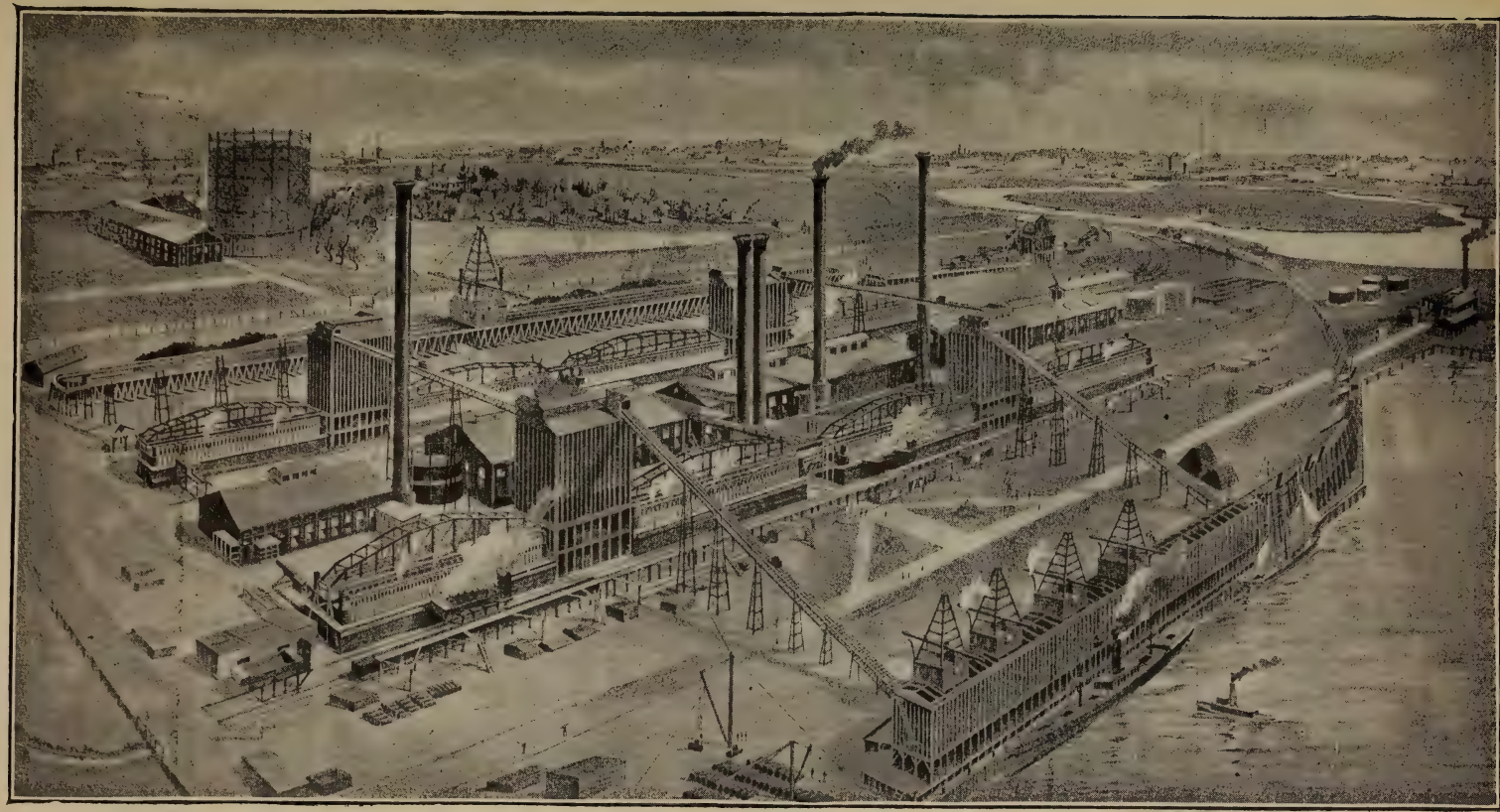


FIG. 7.—NEW ENGLAND GAS AND COKE CO.'S PLANT, EVERETT, MASS.

will of the operators. This system provides a steady supply of coal at the expense of very little labor, and has proved highly satisfactory. In the background are seen the purifying and meter houses, and the immense gas holder, having a capacity of five million feet. The primary object of this plant was to supply Boston with gas, considering the coke as a by-product; so great has been the demand for coke for railway and household use, however, that it now forms the chief product of the plant. The tar is sold by contract to a chemical works located near by, which by fractional distillation, transforms it into marketable productions. The ammonia is all worked into sulphate, and finds a ready sale.

The ovens themselves are of the old Otto-Hoffmann type, 33 feet long, 6 feet in height, 18 inches in width, and have a capacity of six tons of coal. The charge is pushed from the oven by an electrical pusher, and is received and quenched on a loader on the opposite side of the battery, from which it is dropped into railway cars.

The gas system provides for a separation of the earlier and later gaseous products of the charge, the earlier portion, amounting to about 4,500 cubic feet per ton of coal, being rich in illuminating power, is sent to the city mains, while the later product, of low candle power, amounting to 5,000 cubic feet, is returned to the fuel mains for heating the ovens. To provide for excessive or emergency demands for illuminating gas a producer plant has been installed to substitute a portion of the poor oven gas with producer gas, thus permitting a larger fraction of the earlier or rich gas to be taken off for illuminating purposes; the necessary enrichment being added to preserve the candle power. This producer plant makes use of the refuse coke gathered up in the yard, which is unfit for sale.

The Everett plant produces 1,400 long tons of coke per day, which is almost entirely used in Boston or vicinity.

One-half of this quantity is sold to the railways for locomotive fuel, and the remainder is disposed of for steam plants and domestic purposes. The daily output of gas reaches 6,500,000 cubic feet. This is all consumed for illuminating purposes in Boston. It averages nineteen candle power without enriching.

This plant of 400 ovens has been in operation since the autumn of 1898, and has given perhaps the most complete and satisfactory test of the by-product system in America. The company itself has labored under financial troubles, but these were due to defects in organization rather than to any fault of the plant.

THE SUDBURY ORE-BEARING ERUPTIVE.

M. T. Culbert, '02.

The Sudbury nickel and copper deposits occur in that belt of rocks known as the original Huronian of Logan, which stretches from Georgian Bay to Lake Temiscamingue and on to the north-east. The rocks of this series in most prominence in the nickel region are greywackes, quartzites, mica and hornblende schists, porphyrites, clay-slates and olivine-diabases. The ore-bearing eruptive is only present in the Sudbury district, and almost, if not completely, surrounds a series of younger sedimentaries which include volcanic tuffs, black bituminous slates and sandstones. This last series has been referred to the Cambrian by Bell, but so far no fossils have been discovered.

The greywackes are of wider distribution than any other member of the Huronian division, and present many different phases from an almost pure quartzite to a mica-slate. Metamorphism has also changed it in places, and hornblende-chlorite-schists which occur at Copper Cliff and other places have probably resulted from such a cause. A characteristic rock of the region is an interbanded quartzite and slate. The slaty bands have developed a cleavage, some places at an angle with the bedding plane. In the vicinity of eruptives mica-slates have been developed by metamorphic action, and the slaty layers of the original rock are changed to grantiferous-chlorite-schists. The quartzites of the district are rocks corresponding in composition to the siliceous bands of the greywackes, and both are conformable to one another, and together form the oldest clastic rocks of the Huronian belt. They are badly tilted, and dip at all angles.

Diorite porphyrites have been erupted through the sedimentary rocks and form long bands which often lie between the Huronian and the Laurentian. One of these bands runs from Blezard township south-west to Denison township. Phenocrysts of black hornblende in a black groundmass form the characteristic rock of this group. At the Stobie mine the hornblende forms radiating aggregates which, with a little plagioclase, make up the rock. Massive diorites also are found in some places in this band of eruptives, and generally lie near the gneiss.

Among other rocks clay slates occur north of White Water lake and a short distance west of Rayside station. Olivine diabase, in

dikes varying in width from a few inches to two hundred feet or more, is found all over the region, and cuts through all the other rocks, being the youngest of all.

The above mentioned rocks belong to the Huronian proper, with the exception of the olivine diabases. The Huronian belt is flanked on each side by Laurentian gneisses and gneissoid granites, which are younger than the sedimentary rocks, as inclusions of the latter occur in the gneisses, and the granites are eruptive through the clastics. The gneiss formed the floor, probably, on which the Huronian was deposited, and later this floor fused, and the plastic mass broke off large masses of the rocks above it, and sheared the inclusions out into bands, forming the banded gneiss now found. In the townships lying to the west of Lake Wahnapitae large angular masses of schistoze rock form inclusions in a granite. Resorption of the fragments in many places has rendered the granite more basic, and it has become ashen grey as a result, and the dark minerals predominate among its constituents. Shearing force has apparently been absent in this part of the district, or we should find a banded gneiss as usual. Near the Froude mine gneiss lies in contact with the band of basic porphyrites. For a distance of a quarter of a mile from the latter banded gneiss occurs, and finally a gneissoid granite or granite gneiss in which the dark bands are entirely absent.

The younger sedimentary group spoken of before have probably been deposited upon the gneiss, although the two are separated now by an eruptive mass which forms an immense laccolite of which we will speak later. This sedimentary group, referred to above as consisting of volcanic tuff or breecia, black bituminous slate and sandstone, all of which appear conformable to one another, occupies a synclinal trough or fold in the laccolite and gneiss (Fig. 2), the axis of which runs in a direction east north-east from the township of Trill to the townships of Norman and Capreol. The rocks as far as they extend form the valley of the Vermilion river, and as their resistance to glacial action has been uniform the area they occupy is a low level extent. Volcanic activity of an explosive nature has been very pronounced, as indicated by the great bed of tuffs which were the first of the series to be deposited. Then followed the sandstones and slates. These rocks dip at low angles or lie horizontal in consistence with the synclinal fold (Fig. 2).

Between the tuffs, the lowest of the younger clastic group, and the Laurentian gneiss is interposed an eruptive mass forming an im-

mense laccolite. This is the ore-bearing eruptive and is apparently the youngest rock in the region, with the exception of the olivine diabases and some granites which penetrate it. The outcrop of the laccolite almost if not completely surrounds the younger group of sedimentaries which occur only in one continuous area. The relation of the rocks in the field would lead one to suppose the eruptive was the older, but its massive character proves it to have consolidated at depths, and as it is practically undisturbed by eruptions it must have solidified in its present position. Reference to the map (Fig. 1) will give the geographical position of the outcrop of the eruptive mass. This extends from Trill township to the township of MacLennan,

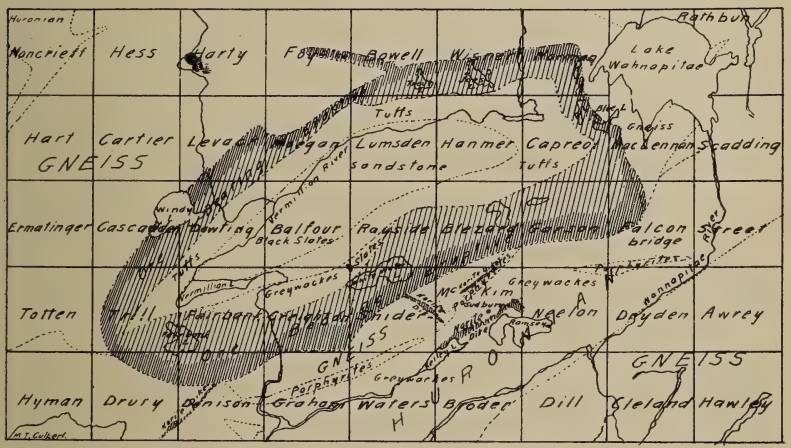


Fig 1 — Map of Sudbury District.

Ore Bearing Eruptive shaded light, Basic Portion shaded heavy.

where it turns north-west for a few miles, then north to the Whistle property in the township of Norman, where it assumes a westward direction to Bowell township. Here the direction turns south-west, returning to the township of Trill, where the outcrop is very probably continuous, although this point remains to be proved during the following summer. The continuity of the rock outcrop in the townships of Morgan and Levack, although never mapped by official geologists, appears, on the strength of statements made by some reliable prospectors, to be unbroken.

Prof. T. L. Walker pointed out, in his paper on the "Sudbury Nickel District," that a transition occurs in the eruptive, from a dark

green basic norite or gabbro through an intermediate micropegmatite to a flesh red granite. In the ideal section (Fig. 2) the basic rock is heavily shaded, while the acid rock is lightly shaded. Reference to the accompanying map will show the outcrop of the rock and the positions of the basic and acid portions geographically, the shading corresponding to that of the ideal section. The map shows the rock to outcrop in the form of a loop or roughly shaped ellipse with the basic portion on the outside and the acid portion on the inside, speaking with reference to the centre of the ellipse. The eruptive dips under the tuff on every side. The maps of the Canadian Geological Survey do not indicate the presence of such a transition, as the fact was not recognized by the geologists who mapped the region in the years 1888-90. Consequently they mapped the acid phase as Laurentian and the basic portion as greenstone, and no indication is given as to both being the same genetically. A band of Huronian appears on the official map lying to the south of the tuff. This is present only in the township of Rayside, and to the west of it, and lies between the eruptive and the volcanic rock.

For further convenience we will speak of the contacts of the eruptive as basic and acid. The basic contact being that of the noritic or gabbroic phase with Laurentian or Huronian, and the acid contact being that of the granitic phase with the Huronian or the tuffs.

Under the microscope the basic rock is shown to have been a norite originally, although it is greatly altered as a rule. The component minerals are plagioclase, biotite, bastite, quartz, hornblende and ilmenite. Other secondary minerals occur as zoisite and leucoxene. Bastite indicates the rhombic pyroxenes to have been present abundantly, hypersthene, in fact, is found in many places, as in Levack township and at the Blezard mine. Chalcopyrite and pyrrhotite occur at the basic border only, and always lie on the contact, and except where occurring in large masses fade out into the rock within a few yards from its edge. Ilmenite generally shows borders of leucoxene. Upon passing into the acid phase many changes are noticed. Micropegmatite, which is entirely absent in the norite, begins to appear, the rock at the same time showing reddish grains to the eye, until the micrographic intergrowth makes up half of the rock. When this occurs the felspars form phenocrysts radiating from which the micropegmatite forms the groundmass of the rock. In the extreme acid phase the granite shows less of micropegmatite, and quartz is very abundant. Hornblende and biotite are the dark minerals of

the granite and orthoclase has mostly replaced the plagioclase, although the latter seems to be present in amount at the acid contact, and this may be accounted for by the rock cooling here more quickly than at other points.

Along the southern outcrop of the eruptive which stretches from the township of MacLennan to Trill township the basic phase always lies in contact with greywacks and gneisses, granites or greenstones. The transition from basic to acid takes place from south to north. In the townships of Capreol and Norman the same takes place from east to west. Again from Norman back to Trill, along the northern range or outcrop, it occurs from north to south. These are important facts, and, as will be seen, have an important bearing on the subject.

The transition from norite to granite shows a decrease relatively in specific gravity and chemical composition. I have taken the liberty to copy the following rock analysis and corresponding specific gravities from the paper by Prof. Walker. The specimens were collected between the Blezard mine and the north end of Whitson lake in a line running approximately north and south, and at right angles almost, to the outcrop of the eruptive which is here about four miles in width.

	1	2	3	4	
SiO_2	49.90%	51.52%	64.85%	69.27%	67.76%
TiO_2	1.47	1.39	.....	0.78	0.46
P_2O_5	0.17	0.10	0.24	0 06	0.19
Al_2O_3	16.32	19.77	11.44	12.56	14.00
Fe_2O_3	.....	0.47	2.94	2.89	.....
FeO	13.54	6.77	6.02	4.51	5.18
CaO	6.58	8.16	3.49	1 44	4.28
MgO	6.22	6.49	1.60	0 91	1.00
K_2O	2.25	0.70	3.02	3.05	1.19
Na_2O	1.82	2.66	3.92	3.12	5.22
MnO	trace	trace	trace	trace	trace
H_2O	0.76	1.68	0.78	0.76	1.01
Total	99.03	99.71	98.30	99.35	100 29
Spec. Grav.	3.026	2.832	2.788	2.724	2.709

Another series of specimens collected along the transition on the main line of the Canadian Pacific Railway near Windy lake in the township of Dowling, gave the following specific gravities, viz.: 2.851, 2.793, 2.722, 2.690, 2.746 and 2.714, starting with the basic phase of the rock. Here the rock is lighter near the centre, but the heaviest

part of the eruptive is the basic part as usual. Weathering may probably have had something to do with this case, as the heavier bases may have reached out, especially on the surface where the specimens were collected. Leaching may have gone further where the lighter specimens come from. The reason for making these statements will be seen in the following pages of this paper.

I have left the consideration of the ore bodies till the last. They always occur at the extreme basic edge and have been originally a component part of the eruptive, being erupted with it and afterwards segregated. The cause of the segregation has been a matter of speculation in the minds of many geologists. Vogt advanced the theory that the Norwegian nickel deposits had segregated from the parent rock towards its cooling edges according to Soret's principle.

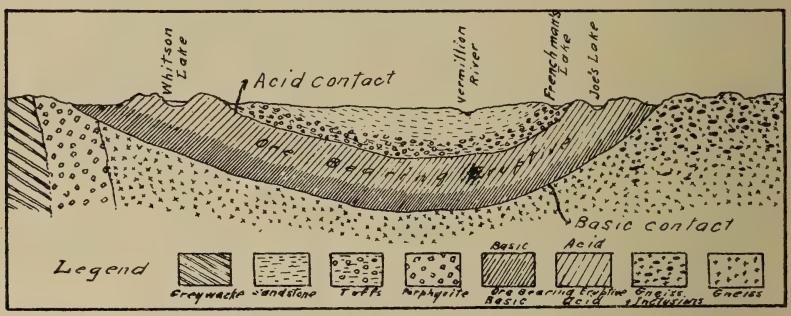


Fig. 2 - Ideal Section, between Lots 4 & 5 Townships of Blezard Hanmer & Wisner on line north and south

Dr. Adams applied this theory to account for the occu rence of the Sudbury ores. This hypothesis did not seem tenable to my mind after examining the deposits along the southern outcrop of the eruptive, and in the townships of Norman and Bowell I first satisfied myself, by tracing the continuity of the southern and northern ranges (See map), that some more profound agency had been at work. The occurrence of the transition in the rock mass, together with varying specific gravity forcibly suggested to me the theory that the eruptive mass after eruption had segregated according to the laws of gravity, and that the ore occurred as an ultra-basic segregation. This theory explains the transition in the rock as well as the position of the ore in relation to the eruptive. Another fact which supports this hypothesis is the occurrence of the largest ore bodies at points where the

basic contact makes sharp bends, as at the Creighton mine and at the Whistle property in Norman township. These bends in the outcrop indicate the position of troughs along the axes of which the ore gathered in mass. Ore is disseminated all along the basic contact, and a continuous band of gossan is found very slight in places, but distinct as a rule, especially on the northern range. Where large ore masses occur they always fade out into the mother rock, which becomes barren in a very short distance. The great difference in specific gravity between the rock and ore would naturally cause the separation of the two to be very complete, and such is the case.

The Copper Cliff mines, and also the Stobie, the Froude, the Worthington, the Victoria, and some others do not occur on the edges of the laccolite, but on dikes of the basic rock. These are probably the channels, through which the mother magma formed at depths found its way to its present position, and they also have been affected by gravitative force. As they lie beneath the main mass they are consequently basic in composition. Before the Ice Age the laccolite must have been of much greater extent, and covered an area embracing the dikes. If glacial action had gone further it would very likely have uncovered many other dikes which lie beneath the laccolite. As it is, we have the channels of eruption distinctly shown in these dikes. Until late years most of the ore has been obtained from dikes, but the greatest deposits occur on the edges of the laccolite. The ore always occurs with the norite or gabbro, although the rock is changed to a diorite as a rule.

To my knowledge, this is the first time that the law of gravity has been assumed to be a factor in the formation of ore deposits. I would suggest that it probably has operated more widely, and has had much to do with the titaniferous ores occurring with massive gabbros. I have never had opportunity myself to examine such ores, and merely suggest it as a factor in their formation. Aside from ore deposits, gravity has probably been a force acting towards differentiation in many rock magmas, during the time before their solidification from a molten state. I hope that in the future many of the problems of petrography will be solved by the application of the theory, that segregation into more or less basic and acid portions or layers takes place in a molten magma, due to the force exerted by gravity. We have a parallel on a small scale in the example of the blast furnace, the action of which is well known to every scientist.

HANDLING DYNAMITE.

W. E. H. Carter, B.A.Sc., Inspector of Mines of Ontario.

This article is intended to deal with that phase of mining operations which entails the actual handling of dynamite from the time the consignment arrives at the mine until it has been loaded into the holes and exploded, the purpose being to set forth as concisely as possible the only safe methods to follow. The presentation of such a subject would be greatly increased in forcefulness if comparison were made with the all too prevalent mal-practices, but unfortunately their very number is such that space and time here will not allow more than an occasional mention. But in their lieu the same end will have been attained if everyone who has to deal with dynamite grasps hard and fast the first principle of the work, which is that instructions for the well defined safe practices must be followed literally and not as with all other mining work altered to suit circumstances.

There are perhaps more risks run in the every-day handling of this explosive than any other detail of the work of mining, and in nearly every case may such recklessness be traced to ignorance of the dangerous properties of the material as the original cause, the later or subsequent carelessness being born of long immunity from accident in its use. And therefore the real astonishment expressed by miners when taken to task for practices which they had for a lifetime considered quite model.

During the first stages of development of a prospect the natural tendency is of course to minimize outlays on plant of every kind, and so in the general curtailment it comes but natural to the unthinking to also adopt makeshift schemes for the storage, thawing and general handling of the dynamite. In this the originality of the miner carries him into wonderfully reckless schemes, and all for the sake of avoiding the outlay of a small sum for proper plant or appliances, and the (imagined) inconvenience attending their use. Such methods are always along lines of mistaken economy, to say

nothing of the perils they involve, for no matter whether the mine be a prospect or a producer this one item of plant for the safe handling of dynamite should be figured into the inevitable expenditures, just as much a necessity as, for instance, is the blacksmith forge to the steel.

Thorough knowledge of the variable actions of this not always certain explosive cannot be obtained alone by either the study of its chemical composition, properties and re-actions, and its manufacture, or alone by a wide personal experience in its practical applications, but by a conjunction of both these sides of the question. Laboratory experiments do not teach, for instance, how to thaw several cases of dynamite at a time in the minimum time possible with safety, nor how to prime a stick, nor how to load a dry back hole, nor a wet lifter, and so on, any more than the simple performance of this work in the field will make the operator sensible of the limits of stability of the explosive during the different processes preparatory and final to blasting; and, therefore, the fact that few but the educated engineer or his staff employ of their own initiattive methods and appliances for handling the explosive that can be said to have a satisfactory degree of safety.

Properly, provision should be made for the reception of the dynamite at the mine before it arrives by erecting a magazine; but if this cannot or has not been done recourse may temporarily be had to some secluded or distant spot where it may lie sheltered from the weather while the magazine is building. In the erection of this, only two really important considerations arise which are first, the choosing of a suitable locality, and second, the design and material most preferable. The first depends largely upon the nature of the country, whether it be hilly or flat. When hilly a variety of choice is possible; but when flat the safeness of any natural location may be made contingent simply on distance.

As safe a rule as one need seek and one which prescribes a suitable minimum limit to the proximity of the magazine to the mine workings under all circumstances is clearly expressed in the Mines Act, Revised Statutes of Ontario, 1897, consolidated form, section 80 (3), which reads: "No magazine of powder, dynamite, or other explosive shall be erected or maintained at a nearer distance than 400 feet from the mines and works, except with the written permission of

the inspector, and every such magazine shall be constructed of materials and in a manner to insure safety against explosion from any cause, and shall be either so situated as to interpose a hill or rise of ground higher than the magazine between it and the mine and works, or else an artificial mound of earth as high as the magazine and situated not more than 30 feet from it shall be so interposed."

This gives adequate scope to the mine manager and to the inspector in the location of a safe site. For instance, if the mine workings should lie altogether on one side of a high hill it would possibly answer all requirements to build the magazine not 200 feet away in a straight line, but around the other side of the intervening hill; while again, if it is desired to overcome the necessity of interposing an artificial protection in the shape of an earth mound, a requirement inserted in the Act more to allow of accommodating certain conditions where proximity is desirable than with the idea of compulsion, the magazine may be moved out to a considerably greater distance than the specified 400 feet, and meet with the sanction of the inspector. This in fact is the usual solution in flat localities. The purpose of the interposed mound of earth is to deflect the force of an explosion upwards, and thus lessen its effect in that direction. Many are not content with putting only 400 feet between their workings and the magazine even though a high hill intervene, but locate the magazine as much as a quarter of a mile off. And in such a case one can but commend their desire for complete immunity from risk. Still there is no sense in going to such a distance that considerable inconvenience results as well as expense in bringing in to the thawing house at the mine the small supply for daily consumption, when a situation answering all requirements is obtainable close at hand.

The liabilities to explosion by forest or bush fires, and by flying rocks from open blasting operations when the mine happens to be a quarry or other form of uncovered pit, also frequently constitute important considerations in the choice of a site. It is just as well in any case to clear away all timber and other combustible material to avoid danger from fire. Also at many mines where it has not been possible to effectually shield the magazine from the perils of a habited vicinity, the other extreme has been resorted to by perching the magazine at a safe distance from the mine workings on top of a conspicuous hill, or on a wide level stretch, with possibly a bright flag fluttering from the peak, in order to give the greatest possible prominence to its locality.

The building should stand near some good highway, or otherwise have such a road built in to it to facilitate hauling in the supplies.

With regard to the design and material of the magazine it may be said that in general the lighter the better, so that in case of an explosion the building will be completely demolished and the radius of danger from flying materials reduced to the minimum. If built of stone or brick work this risk could not be avoided, while the only advantages gained would be the questionable ones of safety from fire and from theft. It is nearly always possible to avoid the former. The latter exists only rarely and locally. The most suitable building is one made of rough or dressed boards on an ordinary wood frame-work with a tight roofing of shingles or, if these are not available, of a combination of tar-paper and boards which will insure waterproofness. The floor should stand a foot or two off the ground, with between the two an unobstructed air passage, and be constructed of dressed tongue and grooved lumber, the walls also lined with the same. Particular attention should be given in both to counter-sinking the heads of the nails. In both side walls on the floor level, openings should be cut for ventilation and covered with wire netting or some such obstruction to the entrance of vermin, and from the roof a hooded pipe projected to complete the means for air circulation. Have the door open outwards and fit it with latch and lock so that at all times when not in use it may be kept securely fastened.

Not infrequently danger of explosion is to be apprehended from stray rifle balls, particularly in this country where hunting forms the pastime of many of those engaged in mining. But safety against these may be efficiently insured by the simple means of lining the interior of the magazine with a sand wall. To illustrate the construction in such a case I quote the results gained by Mr. Courtenay de Kalb in his experiments along this line given in his "Manual of Explosives." He says, "Safety may be insured by constructing inside the magazine a wainscoting with a space of 6 inches between it and the wall, made sufficiently tight to hold fine dry sand with which the interspace should be closely filled. If this is made as high as the top of the pile of cases holding the explosives, and the sand is well compacted and confined by boards covering the sand space, no rifle now manufactured will be able to send a ball through this sand even if fired as close as twenty-five feet from the magazine."

The light frame building as above described is not usually looked on with favor by the ordinary miner, because, as a rule, he has been

accustomed to such heavy structures as log houses or earth houses, or a combination of the two with the upper log work solidly buried beneath several feet of dirt and stones. The explanation of his preference probably originates in the fact that usually lumber is too expensive or not at all available. He has, however, and as a result, come to think of solidity as a prime essential in a magazine, and it is not uncommon to see this carried to the extreme of making use of some out of the way cave or tunnel to store the dynamite in. None of these storage places should be tolerated, except possibly a carefully erected light log house, because they one and all hold dampness, any system of ventilation that may be provided notwithstanding, and dampness will ruin an explosive which contains nitrates either as an essential or an accessory ingredient. The nitrates deteriorate rapidly, the quality being affected in such a way as to prevent explosion of the more badly weathered portions. The visible effect appears in a gradual change in the color of the dynamite from the uniform yellowish brown to a patchy gray, due to the formation of black or dark spots, and a mouldy excrescence on the surface of the paper wrapping. It should in every case be a first consideration to provide for dryness in the place of storage.

In piling the cases in the magazine lay them on their flat side and, in order to better the circulation of air about each, place thin slats between the successive tiers. Unless the dynamite is frozen the boxes should be turned over every week or so to maintain the original uniformity in the composition of the dynamite by preventing the nitroglycerine settling to the side of the cartridge. Too great care in this respect cannot be exercised, since on the uniformity of the blasting charge directly depends the degree of violence of detonation and the avoidance of the perils of unexploded portions, which also are accompanied by excessive generation of poisonous gases.

Nothing but the dynamite should be stored in the magazine, and above all never any detonating caps nor fuse. These latter demand a store-house of their own, not necessarily a separate building, but such a one as, for instance, the general store-house of the mine. The magazine must be kept scrupulously clean, and when dynamite is required the cases must be removed unopened to the small building erected apart at the mine for the purpose of such preparation.

This preparation house is usually called the thawing-house, since in it the dynamite is thawed and prepared for loading and blasting.

The cases should be opened in here, and all the sticks of dynamite at once taken out, wiped clean of the sawdust and then either laid out on racks or replaced in the cleaned box to be drawn on for thawing. Then clean up and carry out all the waste boards and sawdust to some sheltered dump and burn them up. This sawdust, and not infrequently the case itself, absorbs a certain amount of nitro-glycerine, noticeable on the latter by the presence of oily stains, and should not be left lying about to form a menace to the safety of the locality.

No special regulations are laid down for the location and design of this thaw-house since in many cases where the daily supply of dynamite handled does not exceed a few pounds, any small warm shelter such as a box wherein to place the tins answers the purpose provided it be taken away a short distance from the other buildings. When, however, more than a case (50 lbs.) is required at once, it is a matter of economy of both time and labor to provide a separate building wherein all such thawing and preparation of the blasting charges may be confined. The house should be lightly and warmly constructed, similarly to the magazine above described, and located not nearer than 100 feet to any of the workings. To it the supply will be brought every day or two, not to exceed in quantity 200 lbs. when the house stands unprotected from the rest of the buildings.

There are only two safe ways of thawing dynamite. One is in a vessel surrounded by warm water, and the other in a room or house heated by steam pipes, the pipes to be so protected from the explosive that none can come in contact with them. For the first-mentioned practice two styles of galvanized iron or sheet zinc warm-water tins are manufactured and to be had at most hardware stores in the mining centres. Usually the supplying powder company will furnish them. One consists of a system of two pails, the smaller of which forms the receptacle for the dynamite and fits inside the other with a space of two or three inches between for the water; while the other is a rectangular box having horizontal tubes large enough to receive the cartridges and extending from end to end. The preference is with the latter of the two, because in it the cartridges lie flat and the nitro-glycerine has not the same opportunity to leak out as when standing on end in the pails. The temperature of the water must not exceed 125° Fahr., which is about as hot as can be borne by the hand, and it may quickly be tested in this way. When it has been heated to the proper degree in another vessel, and elsewhere than in this building,

into which no stove or fire of any kind beyond a lantern for light at night should ever enter, it is poured into the previously emptied tins either by removing the inner pail of the one thawer, or by means of the funnel mouth of the other, this latter being also provided with an outlet faucet near the bottom.

It seems to be a not infrequent property of dynamite cartridges when thawed to leak nitroglycerine, and this irregularity is due to the imperfect condition of the dynamite, either primarily in the manufacture or developed with age. As a consequence shelves, vessels and any other receptacles in which the cartridge are continually kept become appreciably coated with it and must be frequently and regularly cleansed, the thawing tins at least every two or three days. Ordinary washing with water has practically no effect even on the smooth surfaces of thaw tins, the oily liquor clinging most tenaciously to whatever it touches. It is necessary to chemically destroy its composition, and this is most easily and quickly accomplished with a solution of common carbonate of soda—sal soda or washing soda—applied warm. As an illustration of the futility of attempting to wash it off with water, I recall an accident which occurred a few years ago at one of the large mines in western Ontario. One of the men in looking for a piece of tin found a discarded thawing can on the lake shore where it had lain under water a year or more subjected to the severe washing and pounding of the waves. Carrying it to the blacksmith, they began cutting it up on the anvil with chisel and hammer, when suddenly on a blow of the latter it exploded to pieces, the jagged fragments as well as the hammer flying in every direction and severely cutting and tearing the two men. The explosion was of course caused by the presence of nitroglycerine, which had accumulated when the tin was in use and not been washed out nor destroyed, and not a year's washing by water had sufficed to rub it off. Besides emphasizing the necessity of periodically removing these accumulations of leaked nitroglycerine, this also emphazises the importance of immediately burning up all old refuse with which dynamite has at any time come in contact.

There is a most dangerous type of thawing tin in not uncommon use in some of the western mining camps, though so far as I am aware not in this Province, which it is worth mentioning for the purpose of a warning against its adoption. It consists essentially of one or other of the previously described thawing cans with a base compart-

ment for candle stubs or oil burners which are kept lit to maintain the warm temperature of the water. With the usual intermittent attention given such apparatus, an explosion is most likely to follow sooner or later either from overheating the water, or, following its complete evaporation away, by the consequent overheating of the tins. Besides these reasons the practice at once risks the perils of proximity of fire which should be tolerated under no circumstances.

The water for thawing should never be heated in the thawing tins. No fire of any kind, either candles, matches, pipes or stoves, except in the above mentioned case where a lantern is needed at night for light, should ever enter the thawing-house or indeed ever come into the vicinity of stores of dynamite. To thaw dynamite by means of direct heat from a stove or fire is to run the greatest peril, and even to use the sun's rays entails indirect dangers by the production of leaks and by decomposition. So many "dont's" occur to me on improper methods of thawing that I had better cut short the description of this phase of the work by again emphatically referring to the opening axiom that there are but two *safe* ways, and proceed with the second.

This alternate, when made possible by the proximity of a power plant from which the necessary steam may be obtained, is much the more preferable because of its simplicity, requiring no regular attention and being continuous in action. The interior arrangement of the building provides a suitable number of shelves made of solid dressed boards wider than the length of the dynamite cartridge and affixed to the rear and side walls; also a bench for convenience in preparing the charges. Shelves of slats should never be used because of the liability of the sticks falling through; and store all broken cartridges in a box on the shelf, or otherwise the fragments of dynamite which crumble out on to the shelf may reach the floor. A steam pipe of one inch diameter affixed to the wall along the floor will suffice to heat the building when using live steam, or a single length of a larger pipe for exhaust steam, the coil or pipe to be well protected from falling dynamite or contact with it in any other way by a close wooden grating or other board covering. It is usual to exhaust the steam whether live or exhaust into a water tank outside the room, which prevents overheating and also possible choking up of the system.

Either the powder man who has entire charge of the explosives not only thawing the dynamite, but loading, priming and blasting all holes, or some other competent miner should have full control of the

thaw-house and all operations therein and be held responsible for the same. He will have the key and must see that the room is kept locked when not in use.

It frequently happens that large quantities of dynamite are required to be thawed for use each day at some out-of-the-way place where no steam is available and where there are no mine buildings wherein to heat water for the large number of thawing tins that would be required. In this case it is a question of either erecting two separate buildings, in one of which to keep a stove and in the other thawing tins, or of erecting one structure of non-combustible materials, divided into two rooms by a brick or stone wall. On the one side a stove is set up and on the other the thawing apparatus consisting of a big barrel filled with water in which a galvanized iron or zinc receptacle of adequate capacity for holding the dynamite is suspended. The stove and barrel are then connected through the wall by a pipe system complete in itself and having its own supply of water, an expansion pipe out of the top forming its only outlet. One end enters the stove for contact with the flames and the other the barrel where it is immersed in the water. When heated at the stove the water in the pipes begins circulating up and along the upper pipe to the barrel where, striking the colder temperature of the barrel water, it descends and returns along the lower side of the coil to the starting point in the stove, thus soon warming the water in the barrel and thawing the dynamite. Overheating is impossible by the separation of the two systems of waters.

The primitive method of thawing by immersing the dynamite directly in warm water may be employed only as a temporary convenience; otherwise it is to be strongly condemned since the explosive becomes then un-uniformly saturated with water by absorption, making its subsequent detonation uncertain and causing considerable leakage of the nitroglycerine.

Once dynamite is thawed it is desirable to keep it so, since every re-freezing and re-thawing causes deterioration in strength and ultimately makes its use perilous. It is nearly always possible, however, to closely estimate the quantity required to be thawed for a charge, and any small excess can then be used up on the next occasion. When properly thawed the cartridges will feel uniformly pliable throughout, the lumpiness having gradually disappeared. When partially thawed there is danger of explosion in loading, for dynamite is most

sensitive to shock or friction at temperatures just above its freezing point (about 42° Fahr.). The detonation of the charge also will be incomplete, yielding a less powerful effect and giving off poisonous fumes.

Having thawed the dynamite, the next operation will be the preparation of a number of primers equal to the number of holes to be loaded. The name of primer applies to the cartridge of dynamite into which the cap and fuse are inserted. It forms the last or top stick of a charge, and by its explosion detonates the rest. Some miners prefer to make ready their primers on the surface, in which case a room, preferably the thawing room, should be set aside for the purpose. Others again will cap a number of fuse lengths above ground (this should always be done here) and load the primers with the same at the holes. Both are satisfactory though the former preferable since more convenient and much more likely to be done properly.

The detonating cap consists of a copper capsule containing a quantity of fulminate of mercury with potassium chloride (in the proportions of 3 to 1 respectively), and of a strength depending on the class or grade of the explosive to be detonated. The diameter of the capsule is such that the fuse end fits into it snugly. Then by means of the combined fuse cutter and crimping tool (a variety of pincers) its upper end is then squeezed once or twice on to the contained fuse, leaving annular dints impressed into the soft copper so that the two are bound firmly together. In electric detonators a piece of resistance wire, usually platinum, is embedded in the fulminate with the ends attached to copper wires leading out through a hard plug of sulphur and ground glass which fills the capsule. The heating of the resistance wire by the electric current has then the same effect as the spark from the fuse causing the fulminate to explode, the violence of the shock of which in turn sets off the dynamite. It is necessary when firing with fuse in wet holes to rub axle grease or other heavy grease around the top of the cap in order to make it water tight.

The violence of the discharge of a loading of dynamite depends directly on the violence of the detonation of the primer, and therefore great care should be exercised in the proper preparation of the latter. The correct practice is to open one end of the cartridge paper, and with a round pointed stick of wood of no larger diameter than the cap to gently press a hole into the dynamite to a distance

just a little less than the length of the cap. Insert the cap, close the paper ends in again and tightly bind them around the fuse with string. The same method will be followed when using electric detonators. It is of the greatest importance, in order to realize the full strength of the explosive, to have the cap fit accurately into the hole made for it since any air space of even the smallest fraction of an inch below or around it will serve as an air cushion to check the force of the initial percussion, on which as above noted the violence of the explosion produced directly depends.

When the drill holes have been cleaned out the powder man descends with his load to charge. The holes should of course be large enough for the cartridges to slide or drop in without pressure; but at the same time it is necessary that the charge closely pack the hole under the pressure of the tamping rod. For this purpose the cartridge paper should be slit from end to end with a knife or more safely with a copper blade. After the sticks of the charge have been dropped in one by one, heavy pressure is brought to bear with the rammer until they are packed in solid, or in other words until no air spaces remain, and then the primer is gently inserted. Do not ram or press this, however, but drop in on top of it a depth of several inches of tamping, consisting of any damp clayey or earthy material absolutely free from grit, such as is usually kept on hand in the mine, and then gently pack. Now add more, little by little, each time pressing harder until —without ever actually ramming—the hole from the top down is compactly plugged.

The ramming rod, rather unfortunately named since it should never be used to ram but merely for compressing, is best made out of a young sapling or otherwise a long piece of wood, but never a metal of any kind.

Presuming that the charges have been thus carefully placed, the occurrence of a "miss-fire" will probably cause surprise to any but the long experienced in blasting operations. Such non-explosions are, however, unfortunately all too common and as often as not the result of some extraneous circumstance such as the cutting off of the fuse or the top of the hole by an adjoining charge exploding first. Whatever the cause, they do in fact, either directly or indirectly, result in probably more accidents than any other or all of the other operations of handling dynamite, and nothing but the greatest care subsequently will overcome the attendant perils. Their causes are

too numerous and deep seated to allow of discussion in this curtailed article, besides running off my subject. But of the steps to be taken after one is warned by the under-count of the exploded holes that one or more of the charges has not gone off, I would advise first of all patience. Don't be in a hurry to have a look at it, to arrive maybe just in time to see it fly and then probably see no more—if one is lucky enough to come off alive. The most experienced miners will wait an hour or more knowing the frequent crankiness of the best fuse, which may hold fire in a length of a few inches for several hours and then suddenly jump into the cap. When a sufficient time has elapsed return and loosen the fuse, if possible, and then disappear once more. If nothing results this time proceed to withdraw the tamping with a copper or wooden spoon—never iron or steel—to within a minimum of three inches of the charge, and then re-charge on top of this with several more sticks and another primer and tamping. This will usually explode the whole. If it transpire that the missed hole has been cut off, proceed in the usual way to prime and fire it; but under no circumstances commence mining again until all of the round of shots have been fired. When missed holes lie buried beneath a pile of rock, as in a shaft bottom blast, it is impossible, until this muck has been raised, to get at the holes to fire them. The particular danger in this case lies in the fact that frequently some of the dynamite from a cut off hole will be scattered amongst the rock where it is liable to be exploded by any chance blow of pick or shovel. Only the gentlest handling when removing the rock will avoid accident.

With the progress of underground development the mine workings will in time be so greatly extended that it will be necessary to provide an underground storage place for the dynamite. For this some out-of-the-way disused drift or level must be employed where a box magazine can be placed at a safe distance from all working places to hold the limited supply for complete consumption in one or two days. The Mines Act above referred to deals with this matter concisely and satisfactorily in section 80 (4), which reads as follows : "No powder, dynamite or other explosive shall be stored underground in a working mine in excess of a supply for forty-eight hours, and in no case shall more than 100 pounds be so stored on one level. It shall be kept in securely covered boxes, and located in otherwise unused parts of the mine never less than 10 feet from lines of underground traffic, nor less than 150 feet from places where drilling and blasting

are carried on, and the temperature of such place shall never be less than 60 degrees F. nor more than 125 degrees F."

Although there is no law in this Province stating whether or not dynamite shall be taken into a mine frozen to be thawed there, my own opinion is that this practice should never under any circumstances be adopted. At some of the large mines reasons in favor of it will be urged, the chief of which will be greater convenience; but on looking into the matter in no case have I found any advantage derivable over the practice of first thawing on the surface. The danger lies not particularly in the operation of the thawing, but in the calamitous results to the encaged miners which would follow an explosion. Also on account of the litter in the workings the cases should never be taken below ground unopened, but first opened in the thaw house on the surface, the cartridges removed from and wiped clean of the sawdust packing, thawed, and then replaced in the cleaned case to be taken down to the box or magazine underground, where in the prevailing warm temperature the dynamite will remain thawed.

This box magazine should be fitted with a lid and kept locked by the powder man or shift boss, who is also held responsible for its proper condition and for the distribution of the supply. The clause in the Act which fixes the maximum quantity to be stored at any one time in such a place at enough for not more than 48 hours, is inserted to prevent the deterioration of the dynamite, which would occur should it remain in these unavoidably damp places for longer than that safe period.

Nothing but dynamite should be kept in these boxes, while all articles of steel or iron, or fuse, caps and electric detonators should be removed to a safe distance, not less than 50 feet for the latter materials (fuse and detonating caps), and for these a separate covered box provided. It is necessary to exercise care here as well as on the surface in guarding against the approach to the dynamite of anything containing fire, such as candles or pipes.

In purchasing supplies of dynamite one cannot be too careful to thoroughly investigate its quality immediately on arrival and, if this be found bad, to at once notify the powder company or the agent from whom it was obtained, and then destroy it. Under no circumstances either use any of it or return it, for bad dynamite is fit for nothing, while great risk attends its handling. Take the faulty explosive to

a safe and distant spot and string out the cartridges end to end in a very wide spiral, or, if there are only a few, straight away, and pour paraffine oil or kerosene over the entire train, when on igniting the end with an ordinary fuse, of course not using the cap, it will slowly and safely burn away.

In the face of the number of accidents which have occurred recently in this Province by the use of old, deteriorated dynamite and other similar explosives containing nitrates, I would like to put on record here the suggestion that every case of the explosive have marked on it at the time of packing, and in bold letters, the date on which it was manufactured. By this means the consumer will be enabled to gauge the quality of what he is getting, and will be forewarned against purchasing any dynamite over say a year old, and particularly against second-hand supplies, which, it is a safe rule to follow, should be left strictly alone.

In this connection a valuable service could be performed by the Government, which would indeed be the natural sequence of the existing laws enforcing safe practices of mining, if one of the Departments, possibly that of Mining or of the Inland Revenue, were empowered or required to occasionally check up the quality of the explosives at the mines and at the powder factories by taking samples for analysis, just as is now done by the Inland Revenue Department with other products of home manufacture. Such an enactment might be included in the mining laws or in the regulations of the Inland Revenue, to be carried into effect by the Inspectors of either branch of government. The beneficial results would lie in the improved quality and correct strengths of the explosives turned out by the manufacturer, and in the gradual cessation or ultimate end put to the purchase and use of inferior or deteriorated stock; in the former case by the realization that the output of each factory was kept under close official surveillance, and in the latter case, that of the consumer, by the compulsory immediate destruction of any condemned explosives on hand. Complaints about the under-strength of occasional lots of dynamite would then be less frequently, or not at all heard, while the miner or other consumer would in time accept no explosive without a guarantee and his own personal inspection into its good quality.

ERECTION OF THE NIAGARA RAILWAY ARCH.

J. C. Gardner, '03.

Before commencing the description of the erection of the Niagara Railway Arch, it may not be amiss to give a short history of the structures which heretofore have occupied the site of the present bridge. Each of these old bridges has, in its day, presented new and striking features, each marking a distinct advance in American engineering.

In the year 1844, the Hon. Wm. Hamilton Merritt of St. Catharines, Ont., foresaw the probable demand for a railroad bridge at this point, and in 1846 he succeeded in obtaining charters from the Canadian and American government, for the erection of the first bridge across the Niagara gorge. The site which he chose for the bridge was at a point about two and one-half miles below the well known Horseshoe falls, where the distance from cliff to cliff is a minimum; it is here that the Whirlpool rapids begin.

The earliest means of crossing the gorge was by means of a light iron carriage or cage, which ran on a cable composed of thirty-six No. 9 wires. The charge for transportation over and back was one dollar for each person, and some days as much as $125.00 was taken. The basket or cage is now in the possession of the Buffalo Historical Society. This cableway was used for about a year, and was subsequently used in the construction of the first suspension bridge at this point, known as the Ellet bridge, from the name of the builders.

The Ellet bridge was completed in 1848. Its towers were of wood, and it was without a stiffening truss; this, of course, was not a railway bridge.

The next bridge to occupy this site was the famous Niagara Railway Suspension bridge, the first of the kind ever built. This bridge was designed and built by the late John A. Robeling, A.M. Soc. C. E. The stiffening truss was of wood and was suspended from four cables 10¼″ in diameter, composed of 14,560 No. 9 wires, and

included the cables of the first Ellet bridge. Each cable consisted essentially of a bundle of wires laid parallel and bound together by a wire wound spirally around the outside. The ultimate tensile strength of the four cables was 12,400 tons.

When these cables were removed after 42 years of service the wires were found to be in as good condition as when first placed in position.

In 1880 the wooden truss was replaced by one of metal, and in 1886 it was deemed expedient, owing to the crumbling of pieces of the masonry, to replace the old stone towers with towers of iron. The disintegration of the stone towers was due both to the inferior quality of the stone and to the fact that the rollers under the cable saddles had become so clogged with rust and cement that they were immovable. This latter condition caused a rocking of the towers under a moving load and changes of temperature, and greatly accelerated the disintegration of the masonry. The substitution of the metal for the stone towers completed the work of reconstruction of the Railway Suspension bridge. Nothing of the original structure now remained except the cables, saddles, suspenders and anchorages. This work of renewal was designed and executed by Mr. L. L. Buck, M. Am. Soc. C. E., who was later chief engineer of the Railway Arch bridge.

On account of the ever increasing demand for better railway facilities at this point it was decided by the company to replace the single tracked suspension bridge by a double tracked arch bridge. This change was made in the year 1896-7, without interfering with the running of trains across the bridge. The manner in which this change was brought about is the subject of this paper.

The Niagara Railway arch is technically known as a two-hinged spandrel braced arch. This bridge, though not the longest single arch span in existence, is the heaviest of its kind, its total weight being about 3,000 tons. It has two floors, the upper one carrying the railway and the lower the highway and sidewalks.

The bridge is designed to carry on each railroad track a load of two locomotives, with four pairs of drivers, 40,000 lbs on each pair, followed by a train of 3,500 lbs. per foot, that is a live load of 7,000 lbs. per lineal foot on the upper floor. In addition to this it is designed to carry a live load of 3,000 lbs. per lineal foot on the lower floor,

making in all a live load of 10,000 lbs. per running foot. It will be seen that the whole forms an unusually heavy load.

The main span of the bridge is formed by an arch with horizontal upper chord. This is connected to the top of the bluff by means of trussed spans. The length of the arch is 550 ft., and that of the end spans 115 ft. The arch is hinged at the skewbacks. The distance from the centre of the skewbacks to the top chord is 134 ft., while the centre of the rib at the crown is 114 ft., above the skewback. Each truss has a batter of 1 horizontal to 10 vertical. The width between the centres of the top chord is 30 ft., and between the centres of the rib at the crown of the arch is 56 ft. $7\frac{3}{4}''$.

The outer end of the shore span is connected to the arch by a pin at the point of intersection of the end posts and top chord of the arch, while the shore end rests on expansion rollers on masonry abutments. The hinge at the skewback of the arch is of an uncommon design. A steel casting in the form of a quadrant of a cylinder is bolted to the end of the ribs. A second casting is bolted to the masonry, the lower casting having a concave bearing surface of 6″, greater radius than that of the upper.

The axis of the cylindrical bearing surface is perpendicular to a vertical axial plane of the bridge and passes through the centre of movement of the hinges. Between these two castings is a set of steel rollers formed by taking bars of steel, having a section $1\frac{3}{4}''$ x $6\frac{1}{2}''$, and turning them to a radius of 3″, on the edges. These rollers are set radially with respect to the centre of movement. This form of bearing reduces frictional resistance in much the same way as with ball bearings. As the rollers are easily accessible and can be cleaned readily there is no danger of them becoming ineffective from rust.

The eyebars connecting the rib directly with the lower casting were used to prevent any possible displacement of the upper casting during erection. Between the lower casting and the masonry a rust joint was made, that is, a mixture of 32 parts by weight of cast iron fillings to 1 part of salamoniac was put in between the metal and the stone and very thoroughly rammed.

In locating the skewbacks (or abutments) of the arch span an endeavour was made to so place them that the thrust of the arch would be brought to bear upon the Clinton limestone ledge, which is at this point about half way between the water and the top of the

cliff, and is from 12 ft. to 14 ft. thick. Above this ledge is a blueish grey shale, and below red medina shale running into medina sandstone near the water. The skewbacks on the New York side were made to come very fairly on the Clinton ledge; here the natural rock was cut at the proper angle to receive the masonry directly. But on the Ontario side the conditions were not so favorable, and a bed of concrete had to be used under the front of the south skewback, and under the entire north skewback. The sand and broken stone used in this concrete was deposited between the abutments, in a position convenient for mixing and placing, by means of a wooden box chute

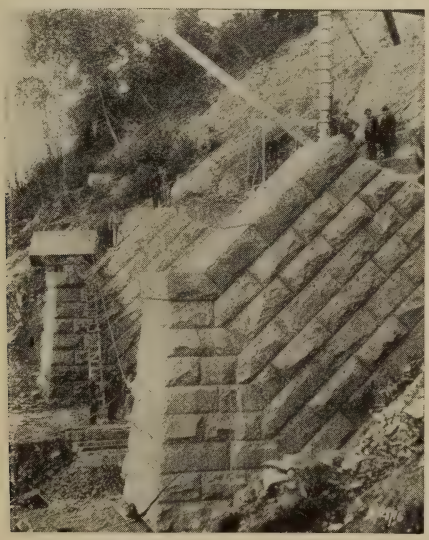


FIG. 1.—SHOWING THE ABUTMENTS.

145 ft. long, suspended from the floor of the suspension bridge and reaching within a few feet of the mixing platform; at about the same point the cement was lowered in bags.

The abutments, fig. 1, are built of limestone with granite copings (dimension stone being used exclusively), all strongly bonded together. By means of a derrick located on the north side of the bridge the large blocks of stone were lowered down the vertical face of the cliff on to a wooded trough or chute, down which they were allowed to slowly slide to the level of the abutments, where they were picked up by a second derrick and placed in position. The maximum

loads per sq. in. on the masonry are: on the top of the coping 339 lbs., under the coping 300 lbs., and on the concrete 113 lbs. The stone in the American abutments is from Chamout, Jefferson Co., N.Y., and that in the Canadian abutments from Queenston, Ont.

After the completion of the masonry, the Pennsylvania Steel Company, who were the contractors for the building of the bridge, began operations. They first constructed timber falsework or scaffolding, fig. 2, on which to rest the end spans during erection. The usual method of erecting an arch by means of scaffolding upon which the structure rests during erection could not be employed in this case, on account of there being a 20 mile current about 100 feet deep in the river at this point. The non-interruption of traffic was another consideration which made the work of erection still more difficult.

The principle of erection carried out was to build out the two halves of the arch as cantilevers, each being anchored to the solid rock on top of the cliff, by means of adjustable anchor chains connected with the arch at the top of the end posts. These anchor chains were constructed from the materials that were afterwards placed in the end spans, with such additional eyebars as were necessary to complete the connection.

Anchor pits 3 ft. x. 6 ft. in section, and 20 ft. deep, were cut in the solid rock, about 180 ft. back from the face of the cliff. At the bottom of these pits the rock was excavated so as to form a chamber of sufficient size to admit the placing of the anchors. After the anchors and the first two sections of the anchor chains were in position the pits were filled with concrete to the level of the top of the rock. The direction of the anchor chains was then brought from the vertical to the horizontal position by means of a "spider," shown in fig. 3, which also gives the details of the adjusting toggle. The diagonal piece is a steel screw $8\frac{1}{2}''$ in diameter and 18 ft. long. The thread on one half is right-handed, and on the other half left-handed, so that when the screw is turned by means of capstan bars which fit into the casting at the lower end of the screw, the nuts on the screw would move to or from the centre depending on the direction of the turning motion. By means of this device the half span of the arch could be raised or lowered by 19 men working each screw. This slide shows the position of the toggle during the erection of the arch, with the eyebars spread widely apart.

FIG. 2.—FALSEWORK IN USE.

FIG. 3.—SPIDER AND TUGGLE.

Travellers built entirely of metal, were used in placing the various members of the new bridge in position. See fig. 4. They rested on the top chord of the arch and were operated by two engines, located in the towers of the old bridge. These travellers were necessarily of a somewhat peculiar design in order that they might clear the cables of the old bridge, and also allow trains to pass underneath; the heaviest piece handled by the travellers was the first section of the lower chord or rib which weighed 32 tons, but their capacity was considerably greater. They were erected on the outer bents of the falsework, one on each side of the river, and from this position handled the skewback castings and the various members of the first panel of the arch.

The first section of the rib rested on light falsework until the end posts and braces of the first panel were erected. After the completion of the first panel the arch span was connected with the anchorages by the driving of a pin at the top of the end posts. The panel was then given its right inclination by means of the adjusting toggle.

The travellers were then moved forward on the first panel of the arch, and in this position handled the materials going into the second panel; this operation was repeated for each of the eight panels, the work being carried on simultaneously on both sides of the river.

Two tracks, over which material was conveyed to the traveller, were used, one on each side of the bridge. These tracks rested on the falsework as far out as the end post of the arch span, and from there out to the centres they were carried by the track stringers belonging to the railway floor, the stringers resting on the sidewalk brackets. These stringers were always placed at their proper panels, ready for raising into their final position when the railway floor should be put in.

In this manner the work of erection was carried on toward the centre as shown in fig. 5. After the eighth or last panel of each half arch had been erected there remained an opening at the centre of 8″, each half arch having been tilted back for the purpose of securing the clearance necessary for the placing of the last panel. As soon as the panels were in position, the screw of the four adjusting toggles were slowly turned at a uniform rate allowing the whole mass of steel to tilt outward until the two half arches met in the centre, thus relieving the anchorages of all strain. The anchor chains and toggles

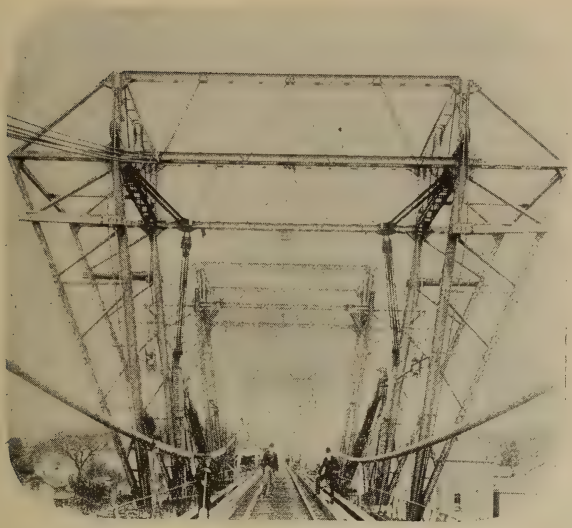


FIG. 4.—SHOWING ONE OF THE TRAVELLERS.

FIG. 5.—PARTIALLY FINISHED BRIDGE.

were then taken to pieces and the parts placed in the end spans. Theoretically, when the two half arches were lowered together the top chords should have met first, and then as the stress in these changed from tension to compression the lower chords should have met. But this is not what actually happened; the lower ribs met first and when the anchorages had been entirely relieved of all strain, there still remained an opening of $\frac{1}{2}''$, between the ends of the top chords. Under such conditions there could be no compression in the top chord, whereas there should have been 350 tons.

This failure to close was probably due to the fact that none of the joints were riveted up at this time, almost all holes being filled with drift pins and bolts. Each connection gave a little; the braces being in tension pulled slightly out of position, and the total movement amounted to considerable when the middle of the span was reached. When, however, certain of the drift pins and bolts were removed from the rib joints, so that their bearing faces came together, the opening at the centre was reduced to $\frac{1}{4}''$.

In order to secure the required amount of compression in the top chord, it now became necessary to force it further apart at the centre and insert a shim. To do this a compression toggle was used. This toggle was improvised largely from the material on the ground. By turning one nut the toggle was compressed on both sides, and with a given pull on the wrench, and by a careful estimate of friction, the required pressure could be very closely obtained. In this manner the top chords were forced apart a distance of 1″, and a shim corresponding to the cross section of the chord and 1″ thick was inserted. The required compression having thus been put into the chord, the compression toggle was, of course, removed.

The next step was the removal of the old Railway Suspension bridge. During the erection of each half arch, the lower floor system had been put in along with the truss, but it was dropped below its final position for the purpose of allowing sufficient clearance between it and the old bridge, in order that there would be no possibility of the weight of the old structure coming upon the new, and thereby putting an unnecessary strain upon the anchorages. (Under extreme temperatures and load the deflection of the old suspension bridge was about 2 ft. 6 in.). This floor system was now raised to its final position. Timbers were laid crosswise on top of the roadway stringers, and at a given time the stiffening truss was blocked up for its entire

length on the new work. The suspenders were then slacked off and removed, and the cables lowered down, one strand at a time on to the bridge where they were cut up for scrap. It is interesting to note that when the strands were cut into short lengths, they coiled up showing that they still retained the set given them by the reels on which they were originally coiled, and that they had not been over-strained.

The cables having been removed the upper or railway floor was put in, this required the removal of the railway floor and the top chords of the old bridge. To do this the old floor system was cut into lengths conforming as closely as possible to the panel lengths of the new bridge, the new floor system for each panel was then placed in position as each section of the old bridge was taken out.

The changing of the floor systems began at the middle, and after the first day, when only one panel was placed, two panels a day were put in until all were in place. Two hours were allowed each day for this work, the time of day being chosen when there were fewest trains, and the work was always done within the time limit. In making this change the same track alignment was preserved and the same rails and ties were temporarily used on the new floor beams and stringers as were used on the old bridge. When the shore ends of the end spans were reached the towers were taken down, a high gin pole being used to remove the upper sections, and the traveller to remove the lower sections.

After the towers had been taken down the new plate girder approach spans were erected. Here the maintenance of traffic was more difficult than on the main span on account of the switches to be taken care of, but the whole work was completed without a single mishap and without the interruption of traffic.

On July 29th, 1897, the bridge was completed, and ready for testing. On account of the difficulty of securing the full load of 10,000 lbs. per lin. foot, it was decided to make up two test trains as heavy as could be made from the cars and locomotives at hand. Each train consisted of two heavy Lehigh "pushers," five of the heaviest Grand Trunk locomotives available, and nine 30 ton capacity coal cars. The cars were loaded with coal, and had as many rails piled on top as was safe for the cars to carry. All together the upper floor carried 14 locomotives and 18 of these heavily loaded coal cars. Besides this some loading was placed on the lower floor, but chiefly

on the end spans. The total load thus obtained was 6,500 lbs. per lin. ft. See fig. 6.

"Theoretically, under a load of 6,500 lbs. per lineal foot, the deflection should have been 1 7-16″ instead of 13-16″, as was actually obtained. The difference $\frac{5}{8}$″ is proportionally considerable, but the actual amount of deflection is too small and existing conditions too far removed from those necessarily assumed in theoretical treatment, to use the deflection as a close check on the stresses. After removal of the load the arch recovered exactly the same camber as it had before

FIG. 6.—FINISHED AND CARRYING THE TEST-LOAD.

the load was applied. The degree of stiffness obtained in this bridge is probably greater than that of any other bridge of equal span. Vibrations due to trains passing over at a rate of 20 miles per hour, are scarcely noticeable, while the generally irresistible jog trot of a horse seldom produces a responsive swing.

In conclusion:—Ground was broken April 9th, 1896, and all work was completed August 27th, 1897, six months having been taken in building the foundations, and 10 months in erecting the bridge.

The writer is indebted to Mr. R. S. Buck, resident engineer, for the use of his notes on the subject.

A GRAPHICAL METHOD FOR COMPUTING HAUL AND OVERHAUL.

STANISLAS GAGNE, '01.

One of the methods for economy in railway construction is to cut sufficiently in the high places to give material to fill the low places. This material has necessarily to be hauled a certain distance to fill those low places, and the aim of this paper is to describe a graphical method by which the amount of material thus hauled and the distance through which it is hauled may be determined.

The method usually referred to in text-books is the centre of gravity method with which most of you are acquainted, but you have, perhaps, felt sometimes, like myself, that it is rather long and tedious.

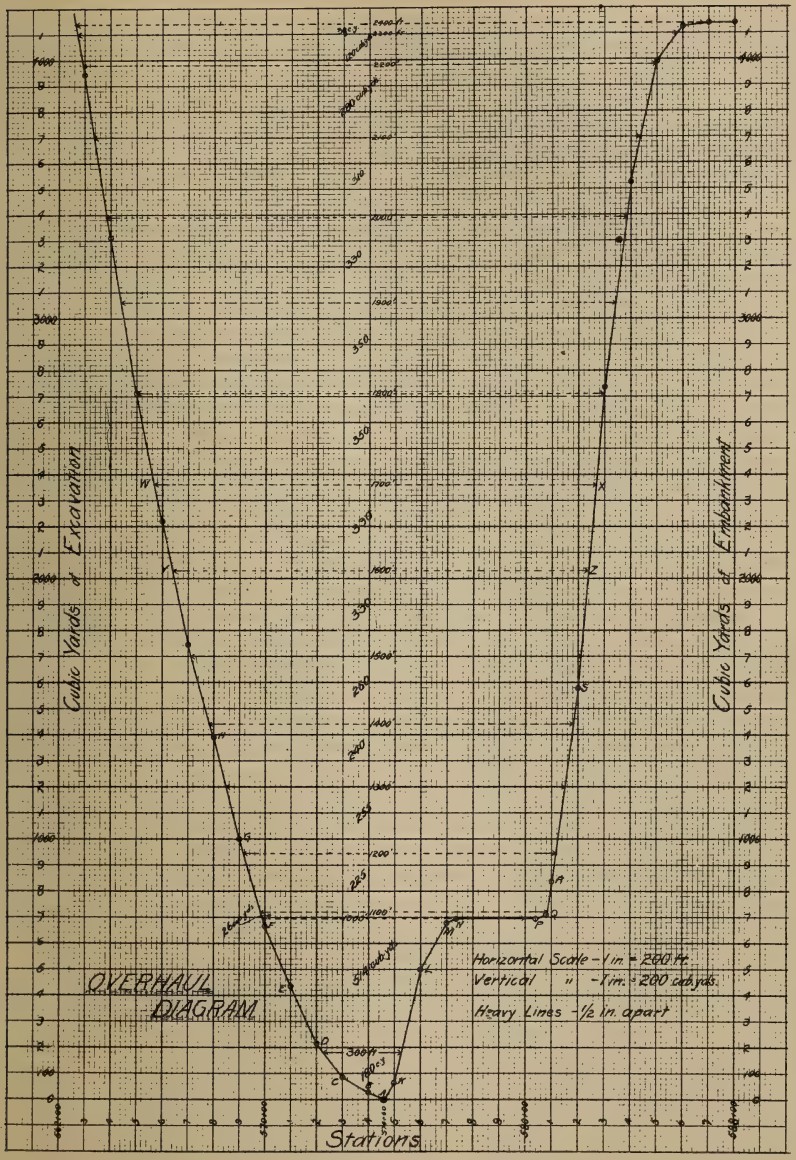
It must be remembered that any method for calculations of earth work gives, at best, comparatively approximate results, accuracy being practically impossible on account of the unevenness of the ground and the roughness of the work; but the errors due to these things tend to compensate one another if reasonable care has been exercised in taking the cross section levels.

To describe this graphical method the writer takes a case which actually occurred on the construction of the V. V. & E. Ry. yards at Grand Forks, B.C. The assistant engineer was required to give the number of cubic yards hauled up to 300 feet, called the 300-ft. haul, the number hauled from 300 to 1,000 feet, called the 1,000-ft. haul, and the number of cubic yards of overhaul, the meaning of which will be understood later.

For this overhaul it was assumed that material hauled over 1,800 feet counted as being hauled 1,900 feet, and similarly for every hundred feet.

Stations	Cubic Yards of Excavation	Cubic Yards of Embankm't	Totals to Each Sta.	Stations	Cubic Yards of Excavation	Cubic Yards of Embankm.	Totals to Each Sta.
562+00			4476			178	
	532			577			679
563			3944			15	
	631			577+35			694
564			3313		0	0	
	602			577+60			
565			2711		3		
	491			578			
566			2220		5		
	475			579			
567			1745		2		
	356			580			
568			1389		1		
	389			580+40			694
569			1000		0	15	
	336			580+80			709
570			664			130	
	229			581			839
571			435			740	
	218			582			1579
572			217			1156	
	132			583			2735
573			85			792	
	58			584			3527
574			27			462	
	19			585			3989
574+50			8			135	
	8	4	×	586			4124
574+70			4			15	
		59		587			4129
575			63			0	
		438		588+00			4129
576			501				

Calculated as 300 ft. Haul Material. 11 cub. yds.


Cubic Yards of Excavation
Cubic Yards of Embankment
Stations
OVERHAUL DIAGRAM
Horizontal Scale - 1 in. = 200 ft.
Vertical " - 1 in. = 200 cub. yds.
Heavy Lines - ½ in. apart

From the cross-section book we have the quantities as given below, i.e., the number of cubic yards of excavation and embankment between each cross-section.

From table No. 1 we see that we change from a cut to a fill between station 574+50 and station 574+70; let us assume that it is at station 574+60.

From that point we sum the cubic yards of excavation up to each station or fraction of it and similarly down for the embankment, leaving out 11 cubic yards of excavation between stations 577+35 and 580+40, which we will add to the 300-ft. haul quantity.

Then we take a piece of cross-section paper as usually supplied by railway companies to their engineers, and plot on it the required diagram as here shown.

Before being reduced, this drawing was as follows. The heavy section lines were one-half inch apart, and the scales thus:—

Horizontal: 1 in. = 200 ft.
Vertical: 1 in. = 200 cub. yards.

and these scales are usually found accurate enough for practical purposes.

After having numbered the necessary stations we plot the point A on the diagram, which represents neither cut nor fill at station 574+60 as seen before. Then we plot the points B, C, D, . . . etc., by finding the distance corresponding to the total number of cubic yards from A up to any station, on the vertical line representing that station, and similarly for the embankment side, that is, for the points K, L, M, . . ., etc., using the figures of the totals column in the table.

It will be noticed that the total at station 580+40 is the same as for station 577+35, because the piece of ground between those two stations is practically at grade and the 11 cubic yards of excavation are counted in the 300 feet haul.

The diagram is then completed by drawing straight lines between these points.

We will now proceed to find the distances required. We take a scale or rule graduated in half inches and find the points where

both lines of the diagram are horizontally 300, 1,000, 1,100, 1,200, etc., feet apart and join these horizontal points. Then the distance between any two of these horizontal lines gives the number of cubic yards that are hauled from one even hundred feet distance to another.

For example, points Y and Z, and W and X on the diagram are 1,600 feet and 1,700 feet apart respectively to the assumed scale, and the distance betwen lines YZ and WX represents 330 cubic yards; therefore 330 cubic yards have been hauled from 1,600 feet to 1,700 feet, this being evident from the construction of the diagram.

After having found these different distances and the number of cubic yards between them as seen in the diagram, we have the following results:

RESULTS.

180 + 11 cub. yds. of 300 ft. Haul
514 cub. yds. of 1000 ft. Haul

OVERHAUL.

26	cubic yards	× 1	=	26
225	" "	× 2	=	450
255	" "	× 3	=	765
240	" "	× 4	=	960
260	" "	× 5	=	1300
330	" "	× 6	=	1980
330	" "	× 7	=	2310
350	" "	× 8	=	2800
350	" "	× 9	=	3150
330	" "	×10	=	3300
310	" "	×11	=	3410
280	" "	×12	=	3360
120	" "	×13	=	1560
39	" "	×14	=	546
4139			Total =	25917

Summing up we have

191 cub. yds. of 300 ft. Haul
514 " " 1000 " "
25917 " " Overhaul.

The contractor is paid a certain price per cubic yard per hundred feet haul over one thousand feet, called "cubic yards of overhaul," remembering again that the number of cubic yards between say 1,700 and 1,800 feet are counted as being hauled 1,800 feet, and similarly for all other distances over 1,000 feet.

If correct overhaul is required we only have to multiply the number of cubic yards between each of the distances by the average of these distances; for example, 260 cubic yards between 1,400 and 1,500 feet would be multiplied by 4.5, instead of 5; or for 1,050, 1,150, 1,250, 1,350, etc., feet of horizontal distance, multiply the numbers of cubic yards between them by .25, 1, 2, 3, etc., respectively.

With a little study of this diagram it will be readily seen that many variations, such as when the material is borrowed or wasted, may be easily worked out in a short time.

This method affords a check towards the end of the operation on the accuracy of the previous part, thus: In the table of results the sum of the number of cubic yards between every pair of horizontal distances should equal the total amount of material removed, i.e., in our case 4,139+11.

There are several other methods for arriving at these results, but this one seems to the writer as simple and short as any.

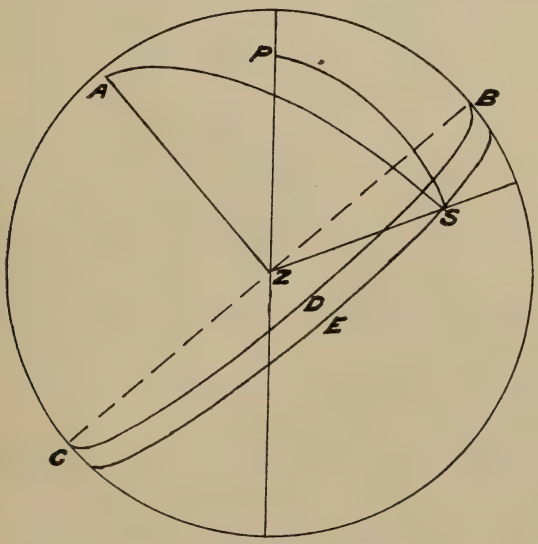
For many problems in practice engineers devise such graphical methods, and as a general rule they save much valuable time.

After preparing the above, the writer found that eleven years ago a similar method of computing overhaul was described before this Society. However, as old numbers of the proceedings are difficult to obtain, it was thought the paper would not be unwelcome.

THE DETERMINATION OF LATITUDE BY OBSERVATIONS OF STARS AT ELONGATION.

L. B. Stewart, O.L.S., D.T.S., Professor of Surveying and Geodesy.

A description of a "new method for the simultaneous determination of latitude and azimuth" by observations of stars at elongation was given in the Sidereal Messenger for April, 1891, by Professor J. S. Corti, of the National Engineering School of San Juan, Argentine Republic, and a discussion of his method by Mr. Otto J. Klotz, D.T.S., is contained in the report of the proceedings of the Association of Dominion Land Surveyors for 1892-3.



In this method a formula is developed which gives the difference of the azimuths —reckoned either east or west from the meridian—of two stars when at elongation in terms of the sum of the azimuths and the declinations of the stars. The sum of the azimuths is measured with the horizontal circle of a transit, and by means of their sum and difference the separate azimuths are found. The latitude is then determined from the azimuth and declination of either star.

When a considerable number of stars have been observed, and especially if the observations have been made with an instrument of the highest precision, a method of reduction by which the observations may be combined by Least Squares will probably give closer results than the method indicated above. Formulæ for reducing by this method may be derived as follows:

In the figure Z is the zenith, P the pole, and S a star at elongation; A is the point in which the horizontal axis of the theodolite intersects the celestial sphere, BDC the great circle of which A is the pole, and SE the small circle traced by the sight line. If, then,

b = inclination of horizontal axis,
c = collimation error,
dR = error in a horizontal circle reading due to instrumental errors,

we have

$$AZ = 90° - b$$
$$AS = 90° + c$$
$$ZS = 90° - h$$
$$AZS = 90° + dR.$$

h being the altitude of the star Then by Sph. Trig.

$$\cos AS = \cos AZ \cos ZS + \sin AZ \sin ZS \cos AZS$$

or

$$-\sin c = \sin b \sin h - \cos b \cos h \sin dR;$$

or, b, c, and dR being small, this becomes

$$dR = b \tan h + c \sec h \qquad (1)$$

(See Chauvenet, Vol. II. p. 320.)

If now

$R_o = R_o' + dR_o$ = true meridian reading of horizontal circle.
$R = R' + dR$ = true reading on star.
A = azimuth of star = PZS

then for an eastern elongation:

$$A = R - R_o$$
$$= R' + dR - R_o' - dR_o$$
$$= (R' + b \tan h) - R_o' + c \sec h - dR_o$$
$$= A' + dA \qquad (2)$$

in which

$$A' = (R' + b \tan h) - R_o'$$
$$dA = c \sec h - dR_o \qquad (3)$$

Again, from the triangle ZPS we have

$$\cos \phi = \frac{\cos \delta}{\sin A}$$

in which

ϕ = the latitude = 90° − PZ

δ = the declination = 90° − PS

Then if $\phi = \phi' + d\phi$, ϕ' being an assumed approximate value of the latitude, we have by (2)

$$\cos (\phi' + d\phi) = \frac{\cos \delta}{\sin (A' + dA)}$$

Then expanding and neglecting the squares of small quantities, this becomes

$$\cos \phi' - d\phi \sin \phi' = \frac{\cos \delta}{\sin A' + dA \cos A'}$$

$$= \frac{\cos \delta}{\sin A'} (1 - dA \cot A')$$

Then dividing by $\cos \phi'$ and assuming that

$$\cos \phi' = \frac{\cos \delta}{\sin A'}$$

in the factor of dA, and substituting the value of dA from (3), we have

$$1 - d\phi \tan \phi' = \frac{\cos \delta}{\sin A' \cos \phi'} - (c \sec h - dR_o) \cot A'$$

or

$$d\phi \tan \phi' - c \sec h \cot A' + dR_o \cot A' + \frac{\cos \delta}{\sin A' \cos \phi'} - 1 = 0$$

By a similar process we find for a western elongation

$$A' = R_o' - (R' + b \tan h)$$

$$d\phi \tan \phi' + c \sec h \cot A' - dR_o \cot A' + \frac{\sin A' \cos \phi'}{\cos \delta} - 1 = 0$$

We have then finally, $d\phi$, c, and dR_o being in seconds

$$A' = R_o' - (R' \mp b \tan h \qquad (4$$

$$d\phi \tan \phi' \mp c \sec h \cot A' \pm dR_o \cot A' + \frac{1}{\sin 1''} \left(\frac{\cos \delta}{\sin A' \cos \phi'} - 1 \right) = 0 \qquad (5)$$

the upper signs being taken for a star at eastern and the lower for one at western elongation.

Each star observed furnishes an equation of the form (5), and the solution by least squares of the equations so formed gives the most probable values of the unknown $d\phi$, c and dR.

In order to be prepared for observation an approximate knowledge of the altitude, azimuth, and hour angle of each star when at elongation is necessary. These may be found by the formulæ

$$\sin h = \frac{\sin \phi}{\sin \delta} \quad \sin A = \frac{\cos \delta}{\cos \phi} \quad \cos t = \frac{\tan \phi}{\tan \delta} \tag{6}$$

In the last of these t is the hour angle of the star (=ZPS) and from this the sidereal time of elongation is found by the equation

$$\theta = \alpha \pm t \tag{7}$$

+ for a western and — for an eastern elongation, α being the star's right ascension.

The approximate meridian reading R_0, if not already known, may be found by adding to or substracting from the reading on one of the stars the azimuth of that star computed by the second of (6). In these computations an approximate knowledge of the latitude is implied.

To ascertain what stars are most suitable for observation we return to the equation

$$\cos \phi = \frac{\cos \delta}{\sin A}$$

and by differentiation we find

$$d\phi = \frac{\cos \delta \cos A}{\sin \phi \sin^2 A} dA$$

$$= \frac{\cos \delta \, dA}{\sin \phi \tan A \sin A}$$

Then substituting

$$\tan A = \frac{\cot \delta}{\cos h} \quad \sin A = \frac{\cos \delta}{\cos \phi}$$

we have

$$d\phi = \frac{\tan \delta \cos h}{\tan \phi} dA \tag{8}$$

This shews that for a given error in the azimuth the resulting error in the latitude is least in the case of a star that culminates as near the zenith as possible, as then δ and ϕ are nearly equal and h is large. In selecting stars then for observation those are chosen

whose declinations exceed the latitude of the place as little as possible; and none should be used whose declinations exceed the latitude by more than about 15°, as then the error in the latitude exceeds that of the observed azimuth.

In order to test the above method the following observations were made by the writer at Toronto on March 28th, 1903. The instrument used was a 10-in. theodolite by Troughton & Simms, the horizontal circle of which is read by two microscopes to single seconds. On sighting each star both microscopes were read, and both forward and backward readings were taken on adjacent divisions of the circle to eliminate error of runs. The striding level was also read for each star. The observations were as follows:

Stars.	Elong.	Hor. Circ	eadings.			Level.	
			Mic. A.		Mic. B.		
		° ′	′	″	′	″	d.	d.
ψ′ Aurigæ	W.	62 20	f. 2	13·2	2	18·0	26·6	29·7
			b. 2	12·5	2	21·7	28·3	27·7
δ Aurigæ	W.	72 45	f. 3	43·4	3	48·4	24·8	31·5
			b. 3	44·0	3	49·0	25·2	31·0
ε Ursæ Maj	E.	176 20	f. 2	18·2	2	09·3	27·0	29·3
			b. 2	18·2	2	14·4	26·0	30·3
69 H. Ursæ Maj	E.	169 35	f. 1	32·4	1	27·0	23·3	33·0
			b. 1	31·0	1	27·4	26·1	30·4
ψ Ursæ Maj	E.	204 15	f. 3	55·2	3	44·6	27·0	29·1
			b. 3	55·7	3	46·3	27·3	28·8
ζ Ursæ Maj	E.	178 15	f. 1	50·3	1	42·3	25 3	30·6
			b. 1	49 9	1	42·8	27.5	28·7
15 Lyncis	W.	80 25	f. 3	06·7	3	07·3	24·2	32·2
			b. 3	06·6	3	07·5	25·3	31·0
27 Lyncis	W.	67 50	f. 1	12·8	1	18·5	24·5	32·0
			b. 1	12·7	1	21·7	27·2	29·4
ι Ursæ Maj	W.	60 00	f. 4	54·6	4	56·8	25·6	30·9
			b. 4	53·5	4	57·8	26·5	30·2
η Ursæ Maj	E.	189 45	f. 1	58·9	1	49·2	25·9	30·8
			b. 1	58·4	1	50·7	28·8	27·8

The declinations of the stars, taken from the Berliner Jährbuch, and the values of A′ found from the above observations, are as follows:

	δ.	A′.
	° ′ ″	° ′ ″
ψ Aurigæ	49 20 15·8	64 14 46·1
δ Aurigæ	54 16 41·7	53 48 22·5
ϵ Ursæ Maj.	56 28 58·8	49 45 10·5
69 H. Ursæ Maj	60 26 36·2	42 59 21·5
ψ Ursæ Maj.	45 01 19·8	77 41 43·7
ζ Ursæ Maj.	55 25 43·2	51 39 41·8
15 Lyncis	58 33 03·3	46 09 01·2
27 Lyncis	51 47 10·0	58 45 51·8
ι Ursæ Maj.	48 25 17.1	66 32 13·8
η Ursæ Maj.	49 47 38·0	63 09 50·6

We have here assumed that

$$\phi' = 43^\circ\ 39'\ 30''$$
$$R_\circ' = 126\ \ 37\ \ 00$$

The observation equations are then as follows:

$$0{\cdot}954\ d\phi + 1{\cdot}165\ c - 0{\cdot}482\ dR_\circ - 2{\cdot}3 = 0$$
$$0{\cdot}954\ d\phi + 1{\cdot}272\ c - 0{\cdot}73^\circ\ dR_\circ - 2{\cdot}9 = 0$$
$$0{\cdot}954\ d\phi - 1\ 510\ c + 0\ 847\ dR_\circ - 5{\cdot}5 = 0$$
$$0{\cdot}954\ d\phi - 1{\cdot}764\ c + 1{\cdot}073\ dR_\circ - 9{\cdot}6 = 0$$
$$0{\cdot}954\ d\phi - 1{\cdot}002\ c + 0{\cdot}218\ dR_\circ - 5{\cdot}0 = 0$$
$$0\ 954\ d\phi - 1{\cdot}450\ c + 0{\cdot}791\ dR_\circ - 10\ 7 = 0$$
$$0{\cdot}954\ d\phi + 1{\cdot}635\ c - 0{\cdot}961\ dR_\circ + 1{\cdot}3 = 0$$
$$0{\cdot}954\ d\phi + 1{\cdot}270\ c - 0{\cdot}606\ dR_\circ + 0{\cdot}7 = 0$$
$$0{\cdot}954\ d\phi + 1{\cdot}128\ c - 0.434\ dR_\circ - 1{\cdot}7 = 0$$
$$0{\cdot}954\ d\phi - 1{\cdot}182\ c + 0{\cdot}506\ dR_\circ - 4{\cdot}7 = 0$$

From these are formed the following normal equations:

$$18{\cdot}429\ c - 9{\cdot}458\ dR_\circ - 0{\cdot}418\ d\phi + 46{\cdot}048 = 0$$
$$- 9{\cdot}458\ c + 5{\cdot}045\ dR_\circ + 0{\cdot}210\ d\phi - 24{\cdot}595 = 0$$
$$- 0{\cdot}418\ c + 0{\cdot}210\ dR_\circ + 9{\cdot}101\ d\phi - 38{\cdot}542 = 0$$

The solution of which gives

$$d\phi = + 4{\cdot}''13 \quad wt = 9{\cdot}092$$
$$dR_\circ = + 5{\cdot}15$$
$$c = + 0{\cdot}24$$

Substituting these values in the observation equations we find for the sum of the squares of the residuals

$$27.9373,$$

whence the probable error

$$r_0 = 0{\cdot}6745\sqrt{\frac{27{\cdot}9373}{9{\cdot}092 \times 7}} = 0{\cdot}45$$

$\therefore$ we have

$$\phi = 43^\circ\ 39'\ 34''{\cdot}13 \pm 0''{\cdot}45$$

The value previously found for the same point, by the transits of nineteen stars across the prime vertical, was

$$\phi = 43^\circ\ 39'\ 34''{\cdot}13 \pm 0''{\cdot}21$$

This close agreement is of course accidental.

The principal source of error in latitude determinations by observing stars at elongation is incorrect pointing to the stars, as is to be expected, and as appears also from the above observations, as the two largest residuals belong to two stars of the second magnitude, which are difficult to bisect owing to their brightness. Stars as bright as the second magnitude should, therefore, be avoided if possible in all precise work.

NOTES AND COMMENTS.

The attention of the graduates and undergraduates of the School of Practical Science is directed to the fact that the Registrar, Mr. A. T. Laing, has offered his services in the matter of furnishing information regarding open situations in their various lines. Two reasons for this undertaking may be cited:—Engineering firms and engineers are continually writing for and complaining that they cannot obtain graduates or undergraduates of the School: also two weeks after the session ends, owing to changes of addresses, the School directory becomes useless as a means whereby the students — all "hard at it" somewhere no doubt—may be located from time to time by the Registrar. It is very desirable that the School of Practical Science should be able to offer the names of suitable men when such requests are received. Will all the graduates and undergraduates kindly see to it that Mr. Laing is kept posted up to date with their addresses, occupations, etc., so that intercommunication on this subject may be possible. Such information as the Registrar could give might often be of interest to men desirous of changing their positions.

You have no doubt noticed the loose sheet among these pages on which is a four-color reproduction of a college pin. It is intended to give you some notion of the new "School of Practical Science Pin," adopted by vote of the students, January, 1903, as our standard pin. The design, by Messrs. F. A. Gaby and A. E. Davison, '03, is one of many submitted, and has been registered by the Engineering Society. The pin can be bought only through the Society. It is not only a School pin but also a year pin, as can be seen from the two raised "year" figures on it. Ambrose Kent & Sons, Toronto (see page 13), manufacture the pins for us, and three options are offered:—sterling silver, gold plated, 50c.; solid 10k gold, $1.25; solid 10k gold with seven small pearls substituted for the white bar between the year figures, $2.00—your own year figures included. It is hoped that every graduate of the School will possess himself of a pin and wear it, so that the ever-increasing numbers of new graduates will have some means of knowing and being known by their predecessors whom they may meet.

The members of the Engineering Society have been meditating upon the necessity of having a special cover design for the annual volume of transactions. They have also been thinking of the advisability of substituting some suitable, short, suggestive, name for our present lengthy title. Suggestions on both questions will be gladly received, and $25 be paid for the chosen cover design.

TREASURER'S REPORT.

Mr. President,—I beg to submit the following statement showing balances, receipts and expenditures for the term ending March 27th, 1903:

To balance on hand March 27th, 1903			$ 142 04
To amount of members' fees	$214 50		
" " of life members' fees	13 00		
" " graduates' donations	30 00		
" " of library proceeds	919 25		
" " from advertising and sale of pamphlet No. 15	184 17		
" " of Government grant	50 00		
		$1,410 92	
Total			$1,552 96

By amount for publishing pamphlet No. 15	$365 55		
" " of printing account	234 07		
" " for paper and supplies	493 32		
" expenses to Reps. to Queen's and McGill	35 70		
" customs	5 69		
" discounts	2 19		
" election expenses	10 50		
" postage and stationery	21 85		
" photos and frames for library	13 10		
" copyrighting pin	5 00		
		$1,186 97	
By balance in Bank of Commerce		365 99	
			$1,552 96

In viewing the finances of the past year it will be noticed that it has been a fairly prosperous one. However, if the Society had

better financial support it would enable us to add many improvements which would be of lasting benefit, both to undergraduate members and the profession at large. To this end, during the past year, donations were received from several life members, but the response was not so general as had been expected. We would suggest that every graduate should be a life member and, by keeping in touch with the work and aim of the Society, could build it up, financially and otherwise, to a prominent place among the Engineering Societies of the continent.

All of which is respectfully submitted.

F. N. RUTHERFORD,
Treasurer.

AUDITORS' REPORT.

We have to-day examined the books of the Treasurer, F. N. Rutherford, and find a balance on hand of three hundred and sixty-five dollars and ninety-nine cents. There are outstanding debts due the society of forty-four dollars.

March 27th, 1903.

F. D. HENDERSON,
W. G. MCFARLANE,
Auditors.

EXCHANGES.

Ontario Land Surveyors, Toronto, Report, 200 copies.
Michigan Engineering Society, Climax, Mich., Michigan Engineer, 125 copies.
Engineering Society, University of Illinois, Champaign, Ill., Technograph, 100 copies.
Association of Civil Engineers, Cornell University, Ithaca, N.Y., Transactions, 100 copies.
Perdue Society of Civil Engineers, Lafayette, Ind., 100 copies.
University of Toronto Studies, Toronto, Ont.
Ontario Association of Architects, Toronto, Ont.
Ontario Historical Society, Education Dept., Toronto, Ont.
Bureau of Mines, Toronto, Ont.
Geological Survey of Canada, Ottawa, Ont.
Queen's University, Kingston, Ont.
Canadian Society of Civil Engineers, Montreal, P.Q.
Canadian Mining Institute, Nova Scotia, Can.
Association of Engineering Societies, Philadelphia, Pa.
Pratt Institute, Brooklyn, N.Y.
Renselaer Society of Engineers, Troy, N.Y.
Colorado School of Mines, Golden, Cal.
Columbia University, New York, N.Y.
American Society of Civil Engineers, New York, N.Y.
United States Coast and Geodetic Survey, Washington, D.C.
United States Tests of Metals, etc., Washington, D.C.
Patent Office, London, Eng.
Institution of Mechanical Engineers, London, Eng.
Royal Institution of British Architects, London, Eng.
Society of Chemical Industry, London, Eng.
Institution of Junior Engineers, London, Eng.
Institution of Engineers and Shipbuilders, Glasgow, Scotland.
Societé des Ingenieurs Civils de France, Paris, France.

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